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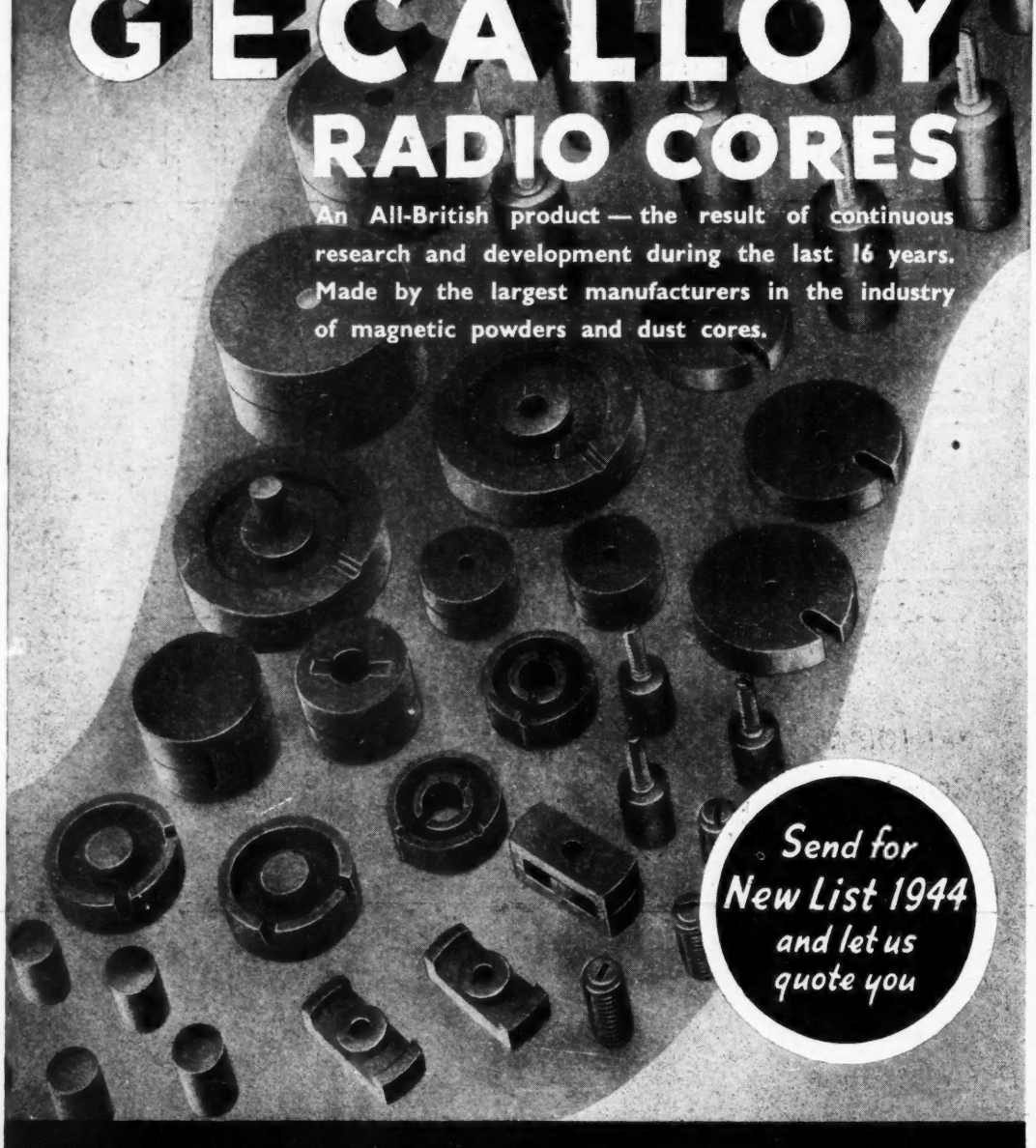
Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

Specialised Metallurgical Products
The Design of Communication Receivers
A New Electronic Analyser
A D.C. Amplifier using a Modulated Carrier
Parallel Operation of Thyratrons

2/- NOV., 1946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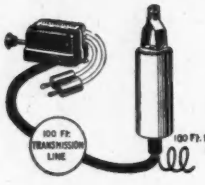
QUIZ (No. 4)

Answers to some of the questions we are continually receiving by letter and telephone

Q.14. *Can a television aerial be used for broadcast reception ?*

A. Yes, in districts where there is little or no interference. Many people have got into the bad habit of doing without an aerial and have never heard their sets at their best because they have always had to operate with the volume control unnecessarily full. When installing a television receiver a television aerial is almost essential, so when it is being erected, an insulated lead should be taken [*1] from the metal cross arm to the broadcast receiver. This lead need not be disconnected when receiving television—it exercises a negligible effect.



Q.15. *Can a television aerial be used as an anti-interference aerial ?*

A. Yes. A Kit [*2] comprising transformers and cable is available, provision being made to secure the aerial transformer to the [*1] cross bar of the television aerial, the rest of the system being carried out as an ordinary anti-interference installation.

Q.16. *Must a dipole and reflector always point directly at the television transmitting station ?*

A. Generally, yes, but an installation department or any people doing a large number of installations know that it is often advantageous to rotate the television aerial slightly one way or the other due to distortion of the polar diagram caused by local conditions at the receiver end. The rotation of the receiver aerial is also often used to improve the "signal to noise" ratio where there is local interference. See next question 1.

(Repeated from Quiz No. 1.)

Q.1. *What are the advantages obtained when using a reflector with a dipole.*

A. (a) It is necessary in areas of weak field strength to increase the signal input to the receiver.

(b) The directional properties can be utilised as a means of minimising interference, particularly so, if the aerial can be installed in such a position that the location of the source of interference is placed behind the reflector in relation to the transmitter.

(c) By rotating the aerial, ghost image can be reduced or eliminated.

Q.17. *What type of plug and socket is recommended for use with L.336 balanced feeder.*

A. The L.303 [*3] range for skirting board terminations and wander plugs for the receiver. The L.303 range are flat pin plugs complying with BSS.613 and are available for flush mounting and proud mounting and in Brown and Cream (Cream in short supply).

. . . TO BE CONTINUED

[*1] Belling-Lee Patent No. 519883., 520628.

[*2] L392/100, £7. 10s.; L392/120, £8 6s., including two transformers. See illustration. Suffix No. denotes length of L1221 feeder cable.

[*3] L.303/F 3-way socket flush mounting, Brown 3/- ; Cream 3/9 each.
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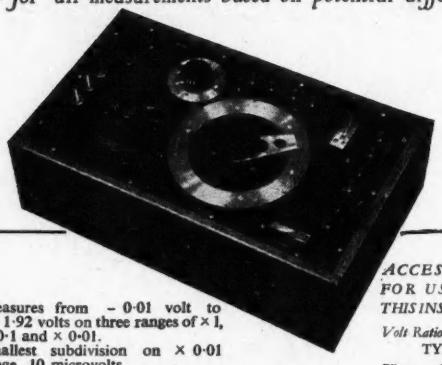

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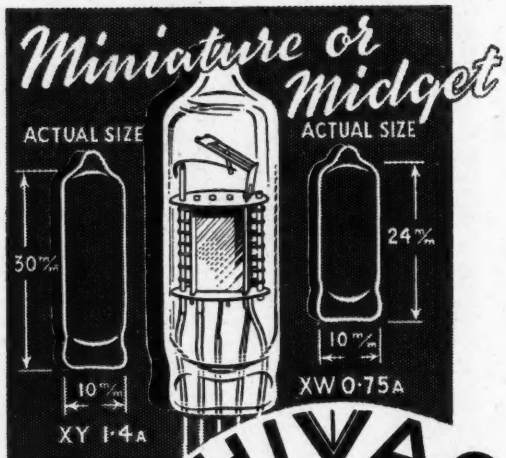

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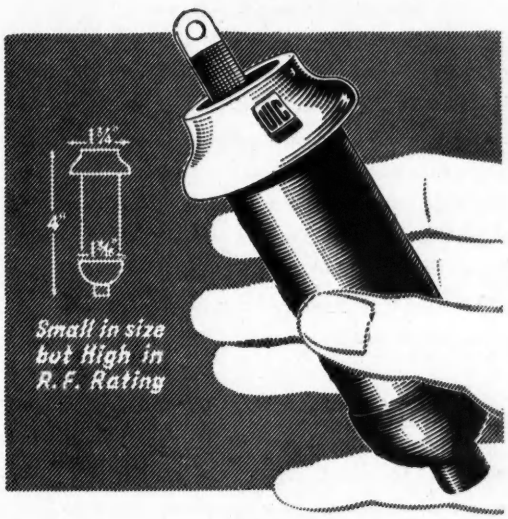

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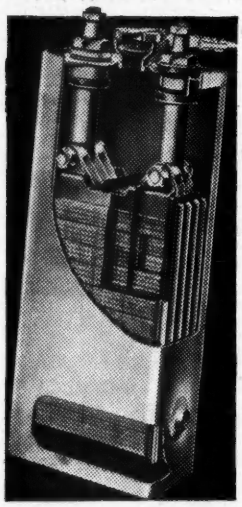

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NOVEMBER, 1946

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Mutual Conductance	3·0mA/V

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B8A and B8B

FROM the time when the all-glass valve base was introduced it was realised that this would mean the adoption of yet another system of basing and another socket. The British Radio Valve Manufacturers' Association have now announced the adoption of two British standard bases for the all-glass valve—the B8A and the B8B.

The B8A, which will be used wherever possible, is the smaller of the two with an overall diameter of 22mm. The pins are located on a pitch circle of 11.5 mm, and in addition to having a centre spigot, there is a boss on one side which fits a locating lip and retaining ring in the valve-holder.

This is an entirely new base and will have connexions which do not correspond with other types. The schedule issued covers a very wide range, including H.F. pentodes with two cathode connexions, double-diode triodes with separate cathodes (very useful) and double triodes (also useful). It will also be possible to use the spigot as a metal connexion to a screen or extra electrode.

The B8B is for larger valves (shell diameter 32 mm., pitch circle 17.45 mm.) and includes the existing 8-pin 'Loktal' range of valves and allows for a spigot which is not grooved.

The Association have already agreed on the policy of producing a standard range of valves which is capable of being manufactured by all its members and which will provide interchangeability among various makes. This standard range will make use of the B8A base, except where power dissipation requires the use of the larger, and will conform to a standard convention for pin connexions.

This announcement of intending standardisation on a new range should be welcomed by the radio industry and all valve users, to whom the multiplicity of bases and conventions has given a headache in the past.

How unfortunate, therefore, to hear the faint jarring note in the flourish that heralds a new era of standardisation :

" It is a fact that in the immediate future a number of new valve types will be issued by various member manufacturers on one or other of the two standard bases, but none of these will be valves within the new standard range."

Did anybody smile ?

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By

G. WINDRED, A.M.I.E.E.

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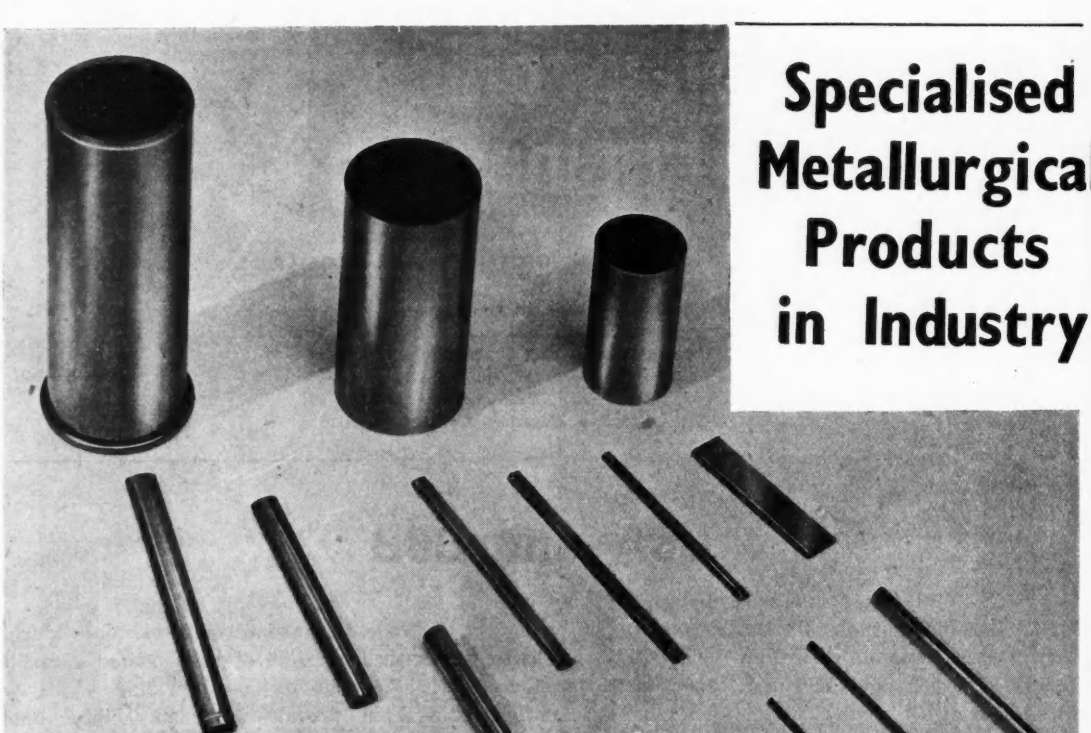
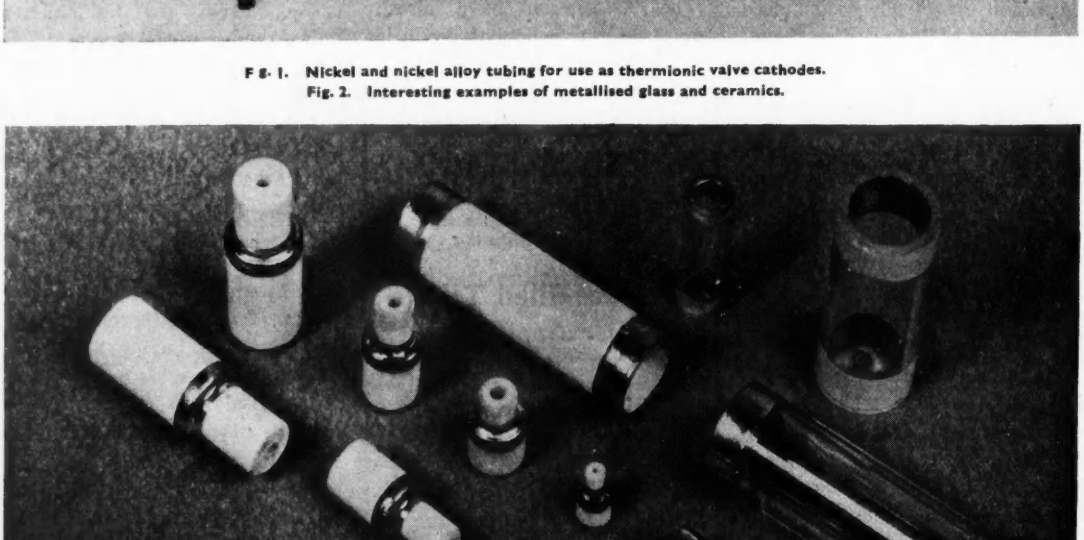


Fig. 1. Nickel and nickel alloy tubing for use as thermionic valve cathodes.
Fig. 2. Interesting examples of metallised glass and ceramics.



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A Description of some Processes and Services now available to Electronic & Telecommunications Engineers

DURING recent years, with the rapid development of electronic apparatus and its application to both war and peace-time aims, it has become more and more necessary to evolve new forms and alternative methods of using constructional materials.

Metals in all their forms play a very large part in this evolution. Often the constructional materials employed are composite in nature, either consisting of two or more similar metals incorporated in one product, or a combination of metal and insulating material. To the electronic engineer the most interesting and useful fields are covered by electrical contact and resistance materials, the use of new forms of metals in thermionic tubes, and the composite forms of metal and glass or metal and ceramic.

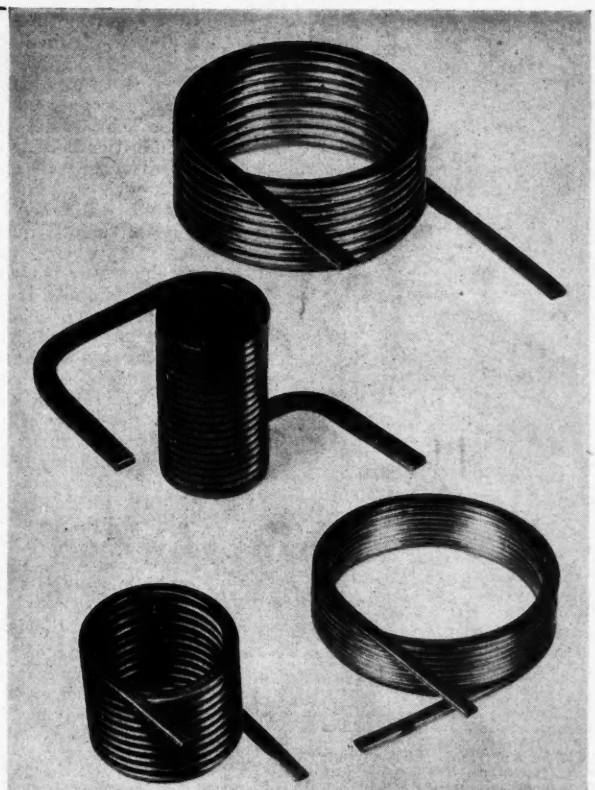


Fig. 3. Examples of work coils for induction heating apparatus.

In the last case, very considerable advances have been made in the past few years and there are now available not only improved methods of applying metals to the insulating material but also improved control of their application to produce a composite product with any desired characteristics.

It is obvious that a close liaison between the metallurgist and the engineer must be maintained in the design of the completed article to ensure that the best use is made of the materials available, and in some cases the metallurgist may even undertake some of the mechanical design prior to handing over to those concerned with the practical embodiment of the component. It is often possible for the metallurgist to advise a modified form of material which will not only meet the requirements but which will actually improve some of the qualities of the finished product.

This is particularly the case with metals to be used under vacuum conditions and in electron devices where the overall performance is largely dependent upon the physical characteristics of the metals used, and of the limitations imposed by the forms in which these metals can be prepared. The metallurgist's responsibilities do not, however, end at this point for he must be capable of specifying the optimum method of working and fabricating his metals to extremely close limits and has to be continually striving, not only to maintain or improve these limits, but to produce his metals in such a form that they can be worked more readily.

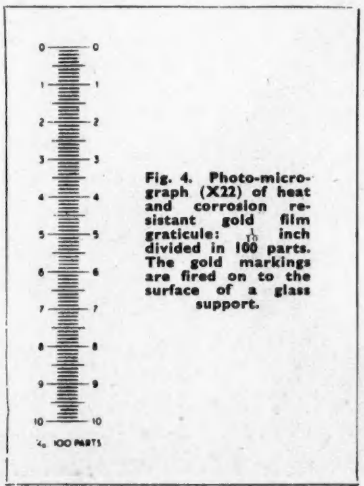


Fig. 4. Photo-micrograph (X22) of heat and corrosion resistant gold film graticule: $\frac{1}{10}$ inch divided in 100 parts. The gold markings are fired on to the surface of a glass support.

Cathode Tubing

Fig. 1 is an interesting case in point concerned with the production of tubing in nickel and nickel alloys for use as thermionic valve cathodes. These tubes, ready for assembly into valve structures, may be made not only to close external and internal tolerances but in an endless variety of cross-sections and special shapes. One of the problems in producing tubes for this work is concerned with maintaining them completely free of contamination from either organic or inorganic materials which would subsequently have a deleterious effect upon their operation in the valve.

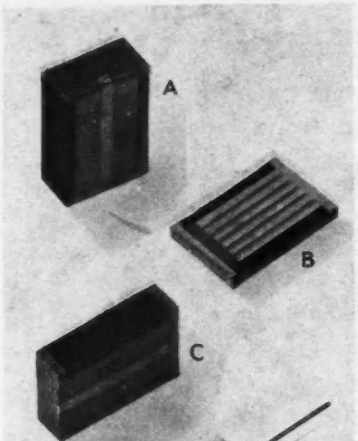


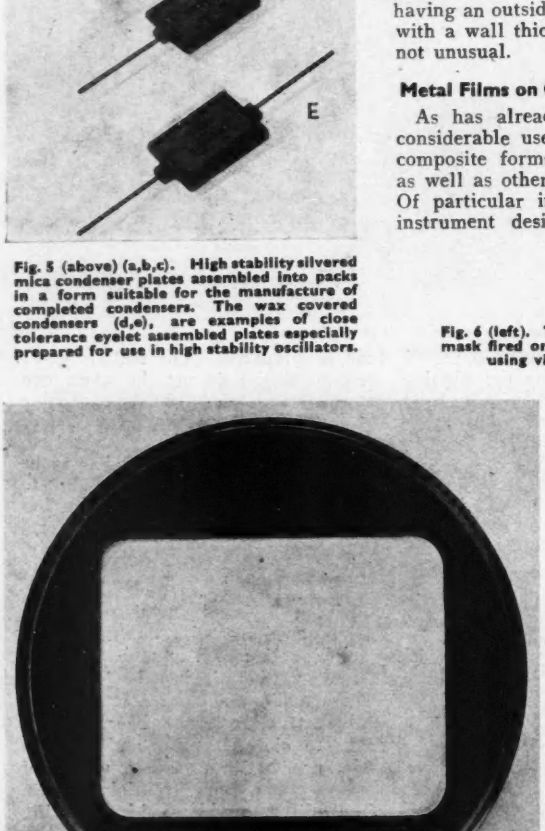
Fig. 5 (above) (a,b,c). High stability silvered mica condenser plates assembled into packs in a form suitable for the manufacture of completed condensers. The wax covered condensers (d,e), are examples of close tolerance eyelet assembled plates especially prepared for use in high stability oscillators.

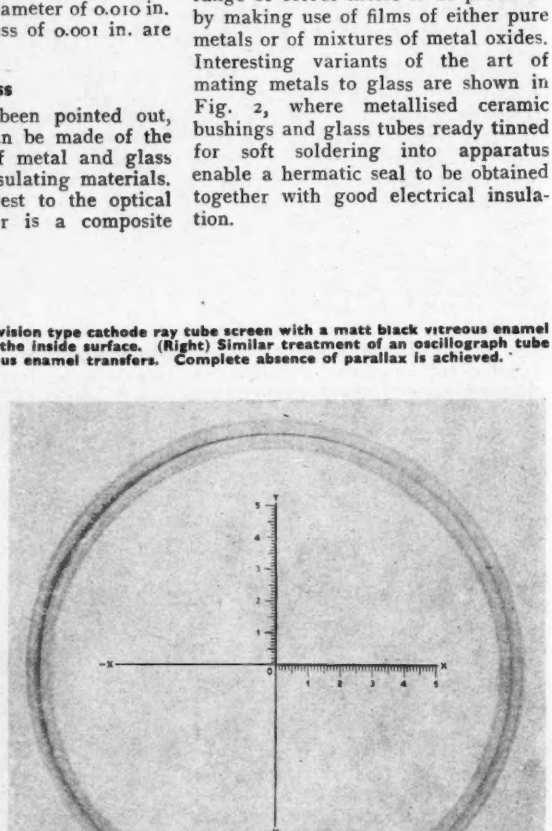
High accuracy tubes are, of course, not always required, but a uniform and flawless product is essential. Fig. 3 illustrates some typical examples of copper tubing of various cross sections wound into coils for use with induction heating equipment, the large diameter coil being for use in low frequency induction melting apparatus, while the smaller types are for use at radio frequencies. In the latter case, where coil currents are high, the tubing is electro-plated with silver to minimise losses. A subsequent protective deposit of rhodium is sometimes used where the local conditions are such that the silver deposit might be damaged by prolonged exposure in corrosive atmospheres. By way of comparison the measuring instrument designer requires a light alloy tube in very small sizes for use as pointers, and tubes having an outside diameter of 0.010 in. with a wall thickness of 0.001 in. are not unusual.

Metal Films on Glass

As has already been pointed out, considerable use can be made of the composite forms of metal and glass as well as other insulating materials. Of particular interest to the optical instrument designer is a composite product of this type in which fine markings may be produced on glass, such as the measuring graticules shown in Fig. 4, by means of an extremely thin film of gold fired on to the surface. This gives a robust, permanent and heat and corrosion resistant scale, electrically conductive and capable of being either a positive or negative image. A process rather similar to this is used in the production of optical filters with a transmission in the blue end of the spectrum, a gold film of accurately controlled thickness being fired on to the surface of a glass support. These are particularly valuable as heat filters due to their small absorption of energy at wavelengths greater than 0.65 microns, by far the greater part being reflected by the gold surface. Modifications of this process enable a range of colour filters to be produced by making use of films of either pure metals or of mixtures of metal oxides. Interesting variants of the art of mating metals to glass are shown in Fig. 2, where metallised ceramic bushings and glass tubes ready tinned for soft soldering into apparatus enable a hermatic seal to be obtained together with good electrical insulation.

Fig. 6 (left). Television type cathode ray tube screen with a matt black vitreous enamel mask fired on to the inside surface. (Right) Similar treatment of an oscillograph tube using vitreous enamel transfers. Complete absence of parallax is achieved.





Closely controlled processing and the use of modern techniques permit the manufacture of silvered mica condenser packs (Fig. 5), to close limits of capacity and having highly stable characteristics. These, of course, would not be of the type normally used in standard radio receivers, but find their rôle in wave filters for carrier telephony and as precision components in high stability oscillators and like apparatus.

In recent years the use of vitreous enamels as a means of marking glass has been prominent in the manufacture of industrial equipment and although apparently having little connexion with metallurgy, metal oxides are used for colouring as in the ceramics industry. Two examples of the use of vitreous enamel to the electronic engineer are shown in Fig. 6. The measuring scale is fired on to the inside surface of the screen of a cathode-ray oscilloscope prior to the application of the fluorescent powder. In the second example a mask has been formed on the screen of a television receiving tube using a matt black enamel over which the fluorescent powder forming the screen is subsequently applied. This gives a mask having no parallax with the picture, while reflexion of stray light inside the tube is reduced, resulting in an improved contrast ratio.

Fig. 7a above illustrates the better known field of specialised contacts, while below (Fig. 7b) are shown examples of rhodium-plated contact elements which have found such a wide field of application in communication and radio-frequency engineering. The thickness of the rhodium deposit is determined by the mechanical and electrical conditions existing in any one particular application, but 0.002 in. is usually considered the thickest practical deposit, while for protection against tarnish 0.0001 to 0.0002 is usually adequate. The outstanding feature of such a rhodium deposit is its extreme hardness and complete protection against oxidation.

Thanks are due to Johnson, Matthey & Co., Limited, for permission to publish this article, and for the use of photographs which are representative of the range of products shown at their recent exhibition at Dorland Hall.

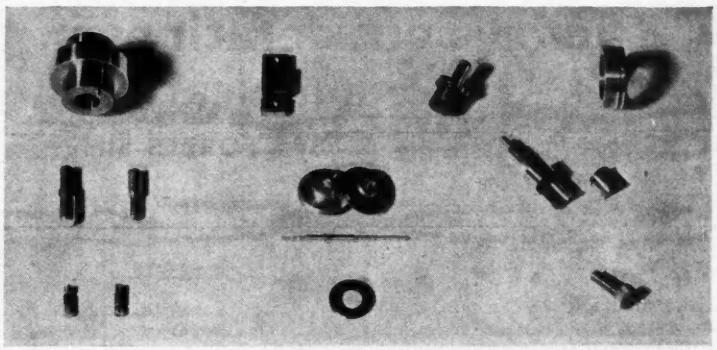


Fig. 7 (a) Specialised contact elements for communication apparatus (b) (below) Silver plated base metals having electrolytically deposited rhodium content faces have a wide field of use in communication and electronic equipment.

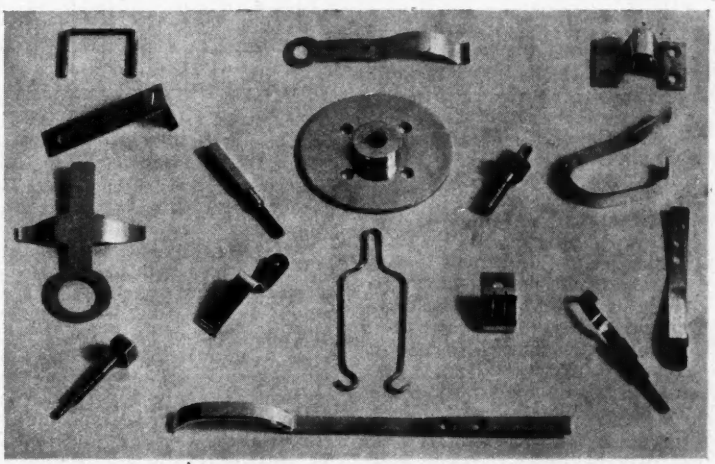
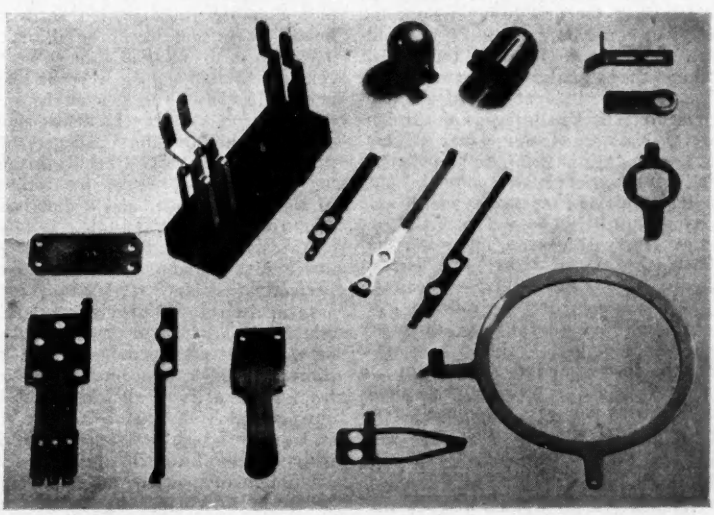


Fig. 8. Typical contact springs and mountings manufactured from beryllium copper, phosphor bronze and nickel silver.



Some Considerations in the Design of Communication Receivers

By I. FORBES SIMPSON*

THE term "Communication Receiver" is very comprehensive, embracing as it does everything between the modified domestic receiver and receivers weighing several hundredweight and occupying many cubic feet.

In this article the term is confined to those which are self-contained and portable or "semi portable" and cover from some 30 Mc/s. to 130 kc/s.

Let us consider in turn the attributes of such a receiver and investigate the compromises which have had to be made in its development. Among the more important attributes are:—

1. Stability.
2. "Resetability" and accuracy of calibration.
3. Sensitivity.
4. A.V.C.
5. Adjacent channel selectivity and image response (*see* 8).
6. Ease of handling.
7. Flexibility in operation.
8. Freedom from whistles, cross-modulation hum, flutter, microphony, radiation, direct and mains borne pickup, etc.
9. Signal strength indication.

(1), (2) Stability, etc.

It will be seen that stability heads the list and that "resetability" follows it closely. As on many occasions the required signal must be received at the first transmission, the receiver must be capable of responding when set to the dial reading at which the signal was last received. This *must* be independent of the temperature, shock, setting of other controls, change of wave range, etc. Presupposing that searching is effected in the least selective condition, this will entail a maximum allowable change in frequency of about ± 15 kc/s. from all causes, including dial backlash. At 30 Mc/s. (the highest frequency considered) this means a stability of 500 parts per million.

As both mis-setting and drift are unavoidable, let us allow ± 9 kc/s. for the former and ± 6 kc/s. for the latter. As 1/20th of an inch is about as much as can be conveniently read by a normal operator, the scale calibration should nowhere exceed 200 kc/s. per inch on a "logging scale."

* The General Electric Co., Radio Works, Coventry

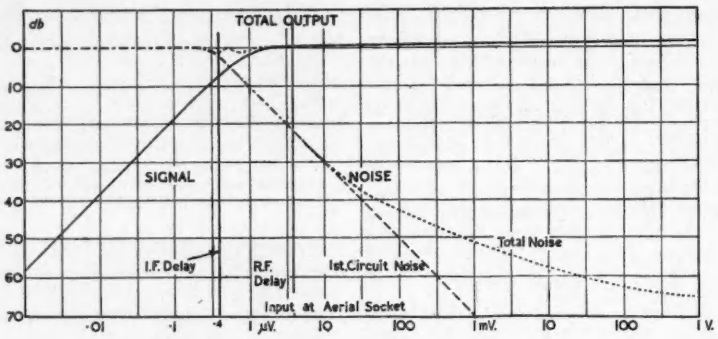


Fig. 1. Typical A.V.C. characteristic for a 30% modulated signal.

Since the rate of change of frequency with rotation is greater at the higher frequencies with a normal condenser law, this will necessitate an effective scale length of about 100 in. for a maximum frequency ratio of 2—1 (30 Mc/s.—15 Mc/s.) on the highest frequency band.

If a normal operator can tune satisfactorily when the rate of change of frequency is 2 kc/s. per degree of rotation, the drive ratio must be greater than 30/1 and preferably of the order of 60/1 or 80/1 for this frequency ratio. Since the movement of the operator's wrist is angular, any increase in size of the tuning knob above some 2 in. in diameter does little to increase the ease of control. Whatever the type of drive and scale chosen, they must be such that reasonable mechanical shock can shift neither the condenser nor the dial setting. The backlash must be less than a ½ degree of rotation of the tuning knob, and a dial backlash corresponding to this.

An oscillator stability of ± 6 kc/s. at 30 Mc/s. under all conditions is perfectly feasible but demands some care in design. If provision is made for the H.T. voltage to be removed, or the receiver otherwise muted for short periods, it is normal to exclude from this drift the initial minute during which the valve heaters are warming. The slow frequency drift with temperature change must be cyclic if any serious attempt is to be made to correct it. Coils and condensers must, therefore, be so constructed that constraint occurs in the same plane as the expansion causing the greatest shift of inductance or capacitance, and the oscillator should be placed in the coolest part of the receiver. Since the percentage drift is normally approximately constant over each tuning range, the temperature frequency correction should be integral in the design of inductances if the drift of the oscillator tuning condenser is small. The same percentage change in frequency is then corrected at all tuning condenser settings, whereas with capacity correction it can only be accurate at one frequency. Stability with shock demands a certain ruggedness in construction, secure fastening of components, etc., and either the counterbalancing of the ganged condenser, or the provision of a flywheel drive. Alternatively, a split worm drive may be used. Stability with supply voltage variation is best assured by using a stabilised H.T. line for the oscillator anode and screening grid, and by coupling the oscillator valve as loosely as possible to the tuned circuit.

It will be obvious from the foregoing that quite a large proportion of the cost will be expended in providing an accurately calibrated stable oscillator and that what one might call the frills may be provided with little extra cost in proportion.

Since the input capacitance of a

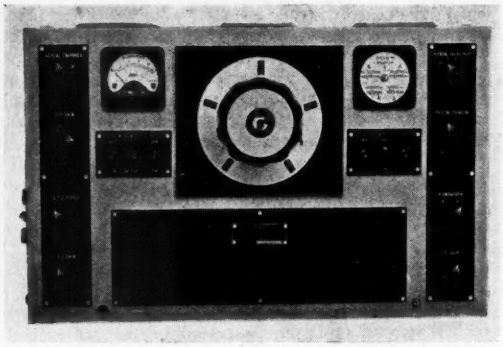


Fig. 3. A communication receiver which exemplifies the number of controls required for 'flexibility.'

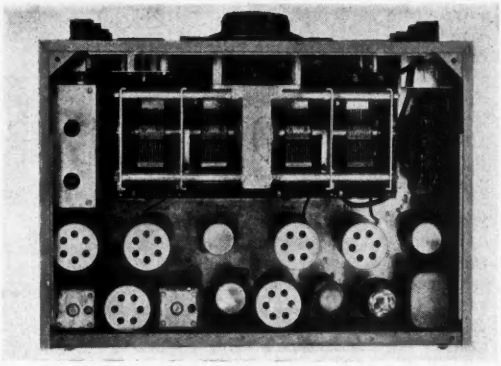


Fig. 4. The same receiver showing the general rugged construction and a low drift worm driven tuning condenser.

valve changes in direct proportion to the initial mutual conductance and the applied bias, the I.F. amplifier should be so designed that this causes no appreciable frequency shift when the A.V.C. voltage varies. Although this contributes little to the long-term stability its effect, which will be dealt with later, may be considerable.

(3), (4) Sensitivity and A.V.C.

Inherent in high gain receivers is the problem of noise, avoidable and unavoidable. Of the former the most usual sources are modulation hum, noisy resistors, valves, etc. The latter is a phenomenon due to the random movement of many millions of electrons each second.

The sum effect of this is the production of a uniform gamut of frequencies of a minute magnitude. The noise output of an amplifier will, therefore, depend on the amplification (M) and the overall frequency response (Δf).

The energy in the thermal agitation noise generated in a tuned circuit, as its title suggests, is proportional to the absolute temperature (T) (*i.e.*, the motion of the electrons) and to the tuned impedance of the circuit (Z_o). Since the noise generated in a valve is due to the random arrival of the electrons at the anode, the noise energy must be proportional to the anode current (I_a).

As energy is proportional to the square of current or of voltage, we may express noise energy as either:

$$\frac{I_n^2}{k_1} \quad \text{or} \quad \frac{E_n^2}{k_2}$$

Thus the thermal agitation noise energy becomes $T.Z_o.\Delta f$, and the noise voltage $E_n = \sqrt{k_2 T.Z_o.\Delta f}$, which is very approximately $1.25 \times 10^{-10}\sqrt{Z_o.\Delta f}$. The noise output is $M.1.25 \times 10^{-10}\sqrt{Z_o.\Delta f}$.

Similarly, the noise energy in the anode circuit of a valve is $I_a.\Delta f$, and the noise component of the current is:

$$I_n = \sqrt{k_1 I_a.\Delta f}.$$

If this is compared with a signal (I_{as}) derived from a voltage (E_{gs}) at the grid, they will bear some ratio (N). The mutual conductance $G_m = \frac{I_{as}}{E_{gs}}$; hence the signal noise ratio $N = \frac{I_{as}}{I_n}$ or $\frac{G_m.E_{gs}}{\sqrt{k_1 I_a.\Delta f}}$ for a given degree of modulation.

It will thus be seen that, other things being equal, the best signal/noise ratio will be achieved with the valve in which the mutual conductance is highest for a given anode current, and with as large a signal voltage as possible at the grid.

Now let us consider the frequency changer; its ratio of conversion conductance to anode current will be worse than the ratio of mutual conductance to anode current for a similar amplifying valve (of the order of ½). Thus for the same signal/noise ratio as could be obtained from an amplifying valve, the signal voltage at the grid must be increased roughly in the ratio of these conductances and the amplification must be sensibly free from noise. This imposes firstly a limit to useful gain in the I.F. amplifier; secondly, a minimum gain in the stage preceding the frequency changer; and thirdly, a minimum gain in the stage before that. This gain should be such that the voltage generated in the frequency changer shall be small compared with that from the first tuned circuit after being amplified in the R.F. stages (say 8 db. below).

The limit to useful amplification in the whole receiver is reached when the thermal noise generated in the first (aerial) tuned circuit, when terminated with an impedance equal to that of the aerial, can fully load the output stage with the receiver in its most selective condition.

To maintain amplification at its useful limit at all frequencies is possible but demands a certain complexity in R.F. couplings, and a minimum of two R.F. stages at the higher frequencies. Assuming this, any received signal is capable of loading the output stage, and the signal/noise ratio for a given pass band is dependent only on the ratio of A.V.C. applied before and after the frequency changer.

Obviously, then, the best possible results are obtained with the I.F. amplifier controlled by an A.V.C. whose delay voltage is just greater than the amplified noise voltage at the A.V.C. rectifier, with the receiver in its most selective condition, and with A.V.C. applied to the R.F. stages, only when the signal/noise ratio is better than some 30 db. with the receiver in its least selective condition. Unless amplified A.V.C. is used the control will be insufficient to prevent overloading of the final I.F. stage with the signals of some 120 db. above those of unity signal/noise ratio, and to prevent overload of the R.F. stages with signals of some 100 db. above the same level. Such an A.V.C. system should be capable of holding the total output constant within ±

1 db. from zero input to one volt, at which level the receiver should be capable of handling a modulation depth of some 70 per cent. or 80 per cent. (see Fig. 1). It is obvious that if provision is made for removing the A.V.C. two gain controls must be fitted, one for the R.F. and one for the I.F. amplifier.

(5) Selectivity

Unless the receiver is designed for one specific purpose, any compromise in selectivity will be poor for all other purposes. For instance, the interference on a particular received station may at times demand a bandwidth of at most 5 kc/s. at 6 db. attenuation, while at other times permit the use of one of some 20 kc/s. Again, for C.W. reception a small bandwidth will suffice, and if a wide bandwidth is used the operator may have to provide aurally the discrimination between two signals of different pitch, a very tiring business.

If the receiver is for general purpose use, the slight extra complication of providing a variable selectivity is far outweighed by its advantages. The bandwidth of the most selective condition is determined by the overall frequency stability of the receiver, as is the attenuation rate in dbs. per kc/s. The latter, however, is also limited in some cases by the H.T. regulation and the A.V.C. characteristic. If a change in signal level and the corresponding A.V.C. voltage change is sufficient to cause a sensible variation in H.T. demand, this in turn may cause a frequency shift in the local oscillator. A condition may then arise where the local oscillator is frequency modulated by this change in anode potential, and rectification occurs of the amplitude modulation of the signal caused by the frequency discrimination of the I.F. amplifier. A form of continuous oscillation sets in which is one form of what is sometimes described as "flutter." If the I.F. amplifier frequency shifts with A.V.C. voltage change, this effect is greatly accentuated. Similarly, if the loudspeaker is so placed that an acoustic feed back path is provided to vibrate the oscillator, continuous oscillations of the same nature occur which may develop into a microphonic howl whose frequency is that of a mechanical resonance in either the loudspeaker or the oscillator circuit. The usual bandwidth limits at 6 db. attenuation are from 500 c/s. with an attenuation rate of some 20 c/s. per db. to some 15 kc/s. with attenuation rate of

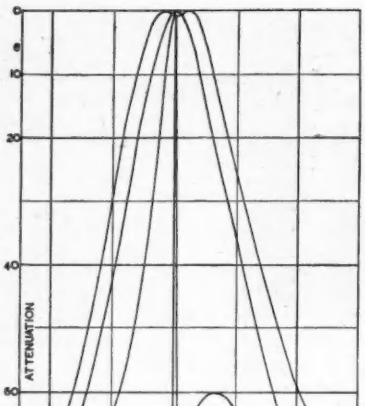


Fig. 2. Typical selectivity characteristics.

0.125 in kc/s. off tune per db. attenuation. (See Fig. 2.)

(6) Ease of Handling

It is almost impossible to assess the ease with which a receiver may be handled without lengthy tests under various conditions by both skilled and unskilled operators. For instance, during searching for a station whose frequency is not definitely known, and whose signal strength is unknown, an operator will be unwilling to reduce the output level on strong signals in case the desired signal is weak and thus missed. In consideration for the operator the output should be of constant level independent of the input and the speed of tuning. The A.V.C. characteristic must therefore be extremely good and have a less selective response than that of the signal circuits. The time constant of the A.V.C. must also be carefully chosen and related to the drive ratio.

(7) Flexibility

Since, without a revolution in technique, no communication receiver can improve greatly on the sensitivity given by some of the better types now in use, and since no two users require the same features, flexibility in operation offers the greatest scope for improvement. The provision of the controls necessary to give this flexibility, while enabling a skilled operator to obtain the best performance possible under any condition of reception, incurs the risk of mishandling by an unskilled operator. Thus, flexibility must be combined with ease of handling. This precludes any simultaneous or progressive adjustment of two or more controls, and demands that the user, by setting controls to definite positions or to give definite readings (*viz.*, the maximum deflection on a meter), shall be able to obtain an adequate performance.

If the controls are placed in two categories, (a) those which both skilled and unskilled operators can be expected to use, and (b) those which should be adjusted only by skilled operators, then the former might be continuously variable while the latter could be either switched controls or such that they permit normal operation if left at one end of their travel.

The table below summarises for each control (a) the precautions to be taken against misuse by an unskilled operator, and (b) the advantages derived from its use by a skilled operator.

WAVE CHANGE
(*a*) Indication must be definite.
(*b*) —

TUNING
(*a*) The motion must be very slow and a tuning indicator must be fitted.
(*b*) Tuning for optimum signal/noise ratio is simpler if a tuning indicator is fitted.

AERIAL TRIMMER
(*a*) A tuning indicator must be fitted.
(*b*) Remarks as for "Tuning" (*b*).

L.F. GAIN
(*a*) A roughly calibrated scale is useful for presetting.
(*b*) A pointer at least is required.

I.F. GAIN
(*a*) Must function at maximum gain without sensible overload on strong signals and must not detune the I.F. amplifier or the oscillator. As "L.F. Gain" (*a*).
(*b*) May be used as sensitivity control without decreasing the signal/noise ratio. It is useful for providing a quiet background on slow C.W. As "L.F. Gain" (*b*).

R.F. GAIN
(*a*) Must function at maximum gain without sensible overload on strong signals and must not detune the oscillator. As "L.F. Gain" (*a*).

(*b*) Is essential to avoid cross-modulation in some conditions. As " L.F. Gain " (*b*).

SELECTIVITY

(*a*) Some deterrent is desirable against tuning in wide bandwidth condition.
(*b*) Should be continuously variable for the best performance in all conditions, but several switch positions will give an adequate compromise.

L.F. CHARACTERISTIC

(*a*) Provision should be made to prevent misuse in conjunction with the selectivity control.
(*b*) Is useful with severe interference to supplement the selectivity control or to give balance to the programme.

NOISE LIMITER

(*a*) Can be safely used if limited to a high percentage modulation level.
(*b*) Can be used with advantage on speech to a low percentage modulation level.

CRYSTAL SELECTIVITY

(*a*) Remarks as for " Selectivity."
(*b*) Remarks as for " Selectivity."

PHASING CONTROL

(*a*) Should never be entrusted to an unskilled operator.
(*b*) It requires an operator of some considerable skill to use this correctly on C.W.

B.F. OSCILLATOR

(*a*) Must not desensitise the receiver nor be " pulled " by the signal.
(*b*) —

A.V.C. TIME CONSTANT

(*a*) Would rarely be correctly used by an unskilled operator.
(*b*) Can often be used with advantage on C.W.

This would suggest that the controls, etc., should be as follows:—

1. Waveband selector; with positive indication.
2. Tuning control; with adequate slow motion and very large scale or vernier device.
3. Signal strength meter; to operate on first circuit noise—preferably logarithmic in calibration for some 120 db.
4. Aerial trimmer, whose setting should stay reasonably constant over each waveband with a given aerial.
5. Normal L.F. gain (volume) control.
6. I.F. gain control which can remain at maximum over a range of signals of some 120 db. with A.V.C. operative.
7. R.F. gain control which can remain at maximum over a range of signals of some 100 db. with A.V.C. operative.
8. Bandwidth control, switched in 3-5 steps from 5 kc/s. to 10/15 kc/s., with 5 kc/s. as normal setting for tuning, and symmetrical about resonance.
9. Bass cut, switched, for balance in most selective positions.
10. Top cut, possibly made inoperative in least selective positions by linkage.
11. Noise limiter, preset with a switch, or variable with a dial calibrated in percentage modulation.
12. B.F. oscillator with a mid-point zero beat.
13. Phasing control with mid-point setting normal and preferably a " click " position.
14. Crystal selectivity separate from bandwidth control to enable phasing control to be used by a skilled operator on telephony.

N.B.—Controls 1, 2, 4, 12 and 13 should give a frequency increment in the same sense as rotation.

(8) Spurious Responses

Spurious responses in a high-priced receiver are more open to objection than in a less costly receiver, and must, therefore, be reduced to a very low level. This entails:—

(a) An excellent R.F. selectivity in two R.F. stages with three or more R.F. tuned circuits.
(b) An excellent I.F./R.F. response ratio.
(c) A sensibly constant local oscillator voltage, the magnitude of which gives minimum harmonic output at the frequency changer
(d) A careful choice of the intermediate frequency.
(e) Effective filtering of the I.F. signal and its harmonics from the audio amplifier and A.V.C. feeds, especially if provision is made for " diversity reception." Failure to ensure this will enable such signals to enter the R.F. circuits and cause beats.
(f) Very high R.F. attenuation paths between the audio amplifier and the R.F. amplifier.
(g) Effective screening of the beat frequency oscillator from the R.F. circuits and suppression of its harmonics.

If we consider these points in turn, we may find that they divide into two groups (1) dependent on layout, and (2) dependent on circuit constants, with a few dependent to some degree on both. It must be remembered that the overall gain is of the order of 100 million, or 160 db. As an example of the effect of small couplings let us suppose that the beat frequency oscillator produces some one volt of intermediate frequency (450 kc/s.) with harmonics attenuated proportionately to their order (*i.e.*, one-half of second, one-third of third harmonic) and suppose a coupling exists with an attenuation of some 100 thousand times (100 db.) between this valve and the aerial circuit. A response will occur greater than the minimum receivable signal at every integral multiple of 450 kc/s. to some 15 Mc/s.

It will be obvious, then, that the layout must be carefully considered to avoid such couplings and that an operationally incongruous position of knobs may have been forced on the designer to obtain the juxtaposition of a control and its appropriate circuit.

Cross-Modulation can occur when the receiver is tuned to a weak carrier and there exists a strong carrier whose frequency is such that it is within the pass band of the R.F. amplifier, but not within that of the A.V.C. amplifier. The unwanted signal may then be many times greater than the wanted signal at the final R.F. valve or frequency changer, while the A.V.C. applied to this stage is insufficient to prevent overload. The only method of automatic prevention is the provision of a separate A.V.C. system for the R.F. valves. This, however, will not give the best compromise in signal/noise ratio for all cases, whereas the provision of an R.F. gain (bias) control will enable the operator to adjust the receiver for the best performance of which the conditions permit.

Where a crystal filter is used, the same phenomenon can occur in the I.F. amplifier, unless the filter is placed in the first I.F. stage.

Although Modulation Hum is caused by lack of smoothing in the R.F. and I.F. amplifiers, it is also dependent on the magnitude of the signal and hum voltages compared with the valve mutual conductance curvature.

This being so, a compromise may have to be made between the signal/noise ratio at small signal inputs and that for large signal inputs. For instance, with a constant A.V.C. amplification the reduction of the R.F. A.V.C. delay voltage may effect an improvement in the signal/noise ratio from 50 db. to 60 db. at 0.1 volt signal input concurrently with a reduction of this ratio from 25 db. to 22 db. at 5 micro volts. The compromise may well be dictated by economic rather than by purely technical considerations.

Flutter, which has previously been mentioned, is a phenomenon which is

not easily assessed. It may be present only under conditions of mishandling or in the presence of signals of a certain magnitude and frequency. The probability of its occurrence, however, is to some degree directly proportional to :—

(a) The carrier frequency.
(b) The attenuation rate of the selectivity curve.
(c) The effectiveness of the A.V.C.
(d) The bass response of the amplifier.
(e) The power output of the receiver.

And inversely proportional to :—

(a) The oscillator frequency stability with supply and A.V.C. variations.
(b) The I.F. amplifier frequency stability with supply and A.V.C. variations.
(c) The regulation of the power supply.
(d) The balance in a push-pull output stage.

Like flutter, Microphony is not readily assessed, and to some degree it may be tolerated, but not if sustained acoustic feedback be obtained with the loudspeaker standing on the receiver. The factors governing its occurrence are sufficient to warrant an article to themselves. The separation of the loudspeaker from the receiver chassis in most communication receivers certainly eases the problem for the designer, and the ruggedness which is required to give long service will normally ensure freedom from microphony. Among the more usual causes are : (a) the use of too closely spaced vanes in the oscillator section of the ganged condenser, (b) insecurely fastened components in the oscillator section, (c) the use of a loudspeaker with an exaggerated surround resonance.

Since communication receivers are normally enclosed in metal cases and since the high stable gain which is required demands adequate screening, radiation and direct pickup are not normally troublesome. Where, however, they do occur, they may often be traced to faulty earth routing or lack of filtering or screening of the supply cables. The screening of the mains transformer does not necessarily remove mains-borne interference where there is any length of cable within the receiver (for instance, switch wiring) and in such cases filtering at the point of entry, or screening, may be required. The user will have to be relied upon to supply the necessary good earth connexion.

(9) Signal Strength Indication

Suppose the receiver be connected to an aerial and no signal is being received. The aerial trimmer is set for maximum noise and the L.F. gain (volume) control is then set to a comfortable level.

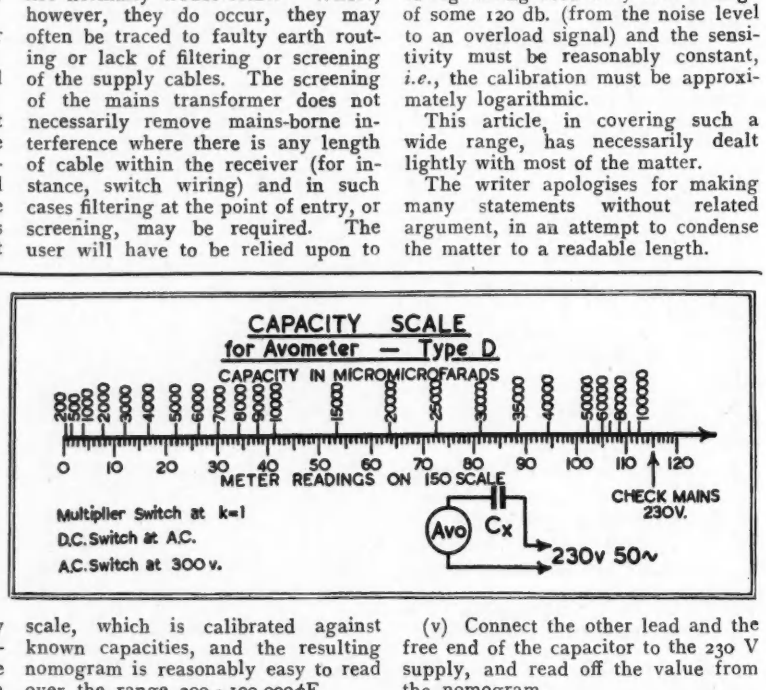
On turning the tuning dial, the total sound energy coming from the receiver will depend almost entirely on the depth of modulation of the stations which have been received. To be tuned accurately, the receiver must either be handled by an operator skilled enough to tune for the optimum signal/noise ratio or a tuning indicator must be fitted. If an indicator is fitted it must be capable of registering accurately over a range of some 120 db. (from the noise level to an overload signal) and the sensitivity must be reasonably constant, *i.e.*, the calibration must be approximately logarithmic.

This article, in covering such a wide range, has necessarily dealt lightly with most of the matter.

The writer apologises for making many statements without related argument, in an attempt to condense the matter to a readable length.

Capacity Nomogram for Use with Avometer Type D.

By R. Terlecki* and J. W. Whitehead†
B.Sc., M.I.E.E.


CAPACITY SCALE
for Avometer — Type D
CAPACITY IN MICROMICROFARADS
0 10 20 30 40 50 60 70 80 90 100 110 120
METER READINGS ON 150 SCALE
CHECK MAINS 230V.
Multiplier Switch at k=1
D.C. Switch at A.C.
A.C. Switch at 300 v.
Avo
Cx
230v 50~

IN the absence of a suitable capacity bridge or similar capacity measuring device, it is possible to use the well-known Avometer Type D for the measurement of capacity. An appropriate nomogram has been prepared which may be fixed to the side of the meter to form an additional capacity scale (*see* Fig.).

The method employed is the insertion of the unknown capacitance in series with the Avometer, which is set on the 300 V A.C. range, the whole being connected across the 230 V 50 c/s. supply.

The reference line is the 0 - 150 scale, which is calibrated against known capacities, and the resulting nomogram is reasonably easy to read over the range 200 - 100,000μF.

It is important to check the supply voltage before making a measurement, suitable correction being applied to the value of the capacity under test.

The following procedure is adopted :—

(i) Set the multiplier to " k = 1."

(ii) Set the " D.C." switch to " A.C."

(iii) Set the A.C. switch to 300 V.

(iv) Connect the unknown capacity in series with one meter lead.

(v) Connect the other lead and the free end of the capacitor to the 230 V supply, and read off the value from the nomogram.

It is realised that the number of Avometers Type D in use outside the Services may be few, but the writers suggest that the above note may be of use to those possessing other Avo models without capacity ranges. The makers state that it would not be difficult to use the Model 40 in this way, but with the A.C. switch set at 120 V and the " *Q* " knob set to give full-scale deflection on the mains supply. Any supply voltage between 80 and 250 at 50 c/s. could then be used in measuring capacity.

* Polish Air Force
† East Barnet Grammar School.

The Parallel Operation of Gasfilled Triodes

By G. WINDRED, A.M.I.E.E.

THE operation of gasfilled triodes or thyratrons in parallel as a means of obtaining increased anode current presents other features and advantages as compared with single tube operation which may give preference to the parallel method of working in certain cases. In this article consideration is given to some of the factors which are of importance in the parallel operation of gasfilled triodes, and alternative circuit arrangements are described.

It is evident that if gasfilled tubes can be operated in parallel so as to share the load equally without the necessity for special adjustments to suit individual pairs of tubes, some important possibilities arise which may be enumerated as follows.

1. In the event of failure of the normal kind, as characterised by loss of emission, either tube may be renewed without interrupting the operation of the circuit, provided that simple precautions are taken for adequate cathode preheating of the new tube before closing its anode circuit. The remaining tube carries the load current, which in general under these conditions will fall below the normal value, until the renewal is completed.

2. Normal failure of one tube does not interrupt the working of the circuit, although the resulting change of anode current may have this effect in some cases, depending upon whether the circuit requires a steady value of current at all times. If the arrangement of the circuit is such that the requisite load current is automatically adjusted, the failure of one tube will result in overloading, or at least increased loading, of the remaining tube until the faulty tube is replaced.

3. Parallel operation of two small tubes may be more economical than a single large tube if the differences between the ratings of individual tubes would necessitate a rating much higher than the load requirements. As the tube life lengthens with reduced loading there is a further indication for the parallel operation of two tubes when by this means the individual anode currents can be brought below the nominal rating.

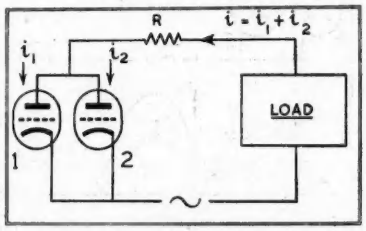


Fig. 1. Simple parallel connexion of gasfilled triodes.

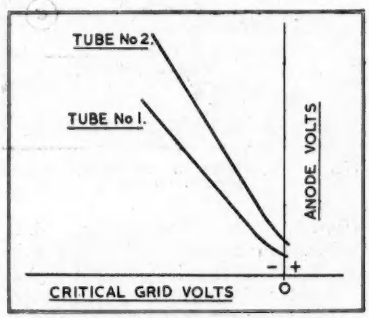


Fig. 2. Variation of critical grid voltage characteristics.

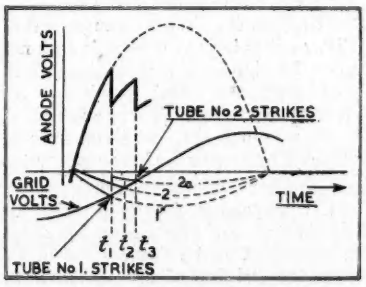
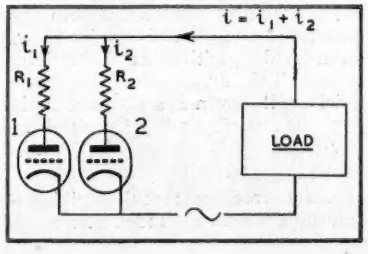


Fig. 3. (above). Delay in striking with phase-shift grid control.

Fig. 4 (below). Improved circuit for parallel operation of gasfilled triodes.



An application in which the foregoing features are of interest is represented by automatic servo or positional control systems; especially in cases where maximum dependability is essential and the possibility of stoppages due to tube failures must be minimised. There are, of course, numerous other cases in which the same considerations apply, and in all these the advantages of a parallel arrangement of output power tubes is worth consideration in the design stage. With regard to vacuum tubes which may be used in conjunction with the gasfilled triodes, the normal life is generally very much longer and the safety factor can be made quite large in a given case because of the wide range of available ratings, without recourse to methods of duplication.

The Simple Parallel Circuit

The simplest form of circuit for the parallel operation of two gasfilled tubes is shown in Fig. 1. The anodes and cathodes are directly interconnected, so that the anode voltage across both tubes is always the same. The resistance R in the anode circuit is not always used, but is generally necessary for current adjustment.

This form of circuit is not generally satisfactory with gasfilled triodes owing to the fact that the anode voltage of both tubes becomes equal to the arc drop (usually between 12 and 20 volts) when either tube strikes, and the effect of differences between the grid control characteristics of the respective tubes. Such differences exist normally between new tubes, and in any case will develop during use even if the tubes are originally matched in this respect. If, for example, the tubes have the characteristics shown in Fig. 2 and the grids are interconnected, tube No. 1 will always strike first with a given change of grid voltage. The resulting drop in the anode voltage does not affect the tube which is already conducting, but the effect of the drop on tube No. 2 is to reduce further the critical grid voltage, which is proportional to applied anode voltage as shown in

Fig. 2, and thus delay striking of this tube.

The conditions applying to phase-shift grid control are shown in Fig. 3. Curves 1 and 2 are the critical grid voltages for tubes No. 1 and No. 2 respectively. With falling negative grid voltage, tube No. 1 strikes first, but the drop in the anode voltage, as already explained, causes the critical grid voltage of tube No. 2 to assume correspondingly lower values, as represented by curve 2a. It is seen that this has the effect of delaying the striking point of tube No. 2 until instant t_{2_1} instead of instant t_2, corresponding to the full-voltage characteristic. Tube No. 1 accordingly supplies the anode circuit current by itself in each conducting half-cycle during the period from t_1 to t_2. The significance of this fact insofar as the tube rating is concerned will obviously depend upon the circuit arrangement. It will also be understood that the conditions represented by Fig. 3 are somewhat idealised, and that oscillograph observations, which provide the only reliable evidence in such cases, will vary considerably with individual circuit conditions.

An Improved Circuit

The conditions may be improved by rearranging the circuit as shown in Fig. 4, where R_1, R_2 are resistors of equal value connected in the respective anode leads. Other things being equal, each resistor will have twice the ohmic value of the single resistor shown in Fig. 1. It will be seen that with this arrangement, if No. 1 tube strikes first, for example, the resulting drop in resistor R_1 is added to the arc drop voltage applied to tube No. 2. The reduction of voltage across tube No. 2 due to the striking of No. 1 is thus lessened as compared with the Fig. 1 arrangement, and tube No. 2 accordingly strikes earlier than in the case of the simple parallel circuit.

The striking conditions can be investigated by means of a cathode-ray oscillograph connected between the cathodes and the junction of the resistors so as to show the position of the respective striking points as indicated by successive drops in voltage. For checking the tube ratings with the maker's data the individual anode currents should be measured. Average values are readily obtained by moving-coil ammeters connected in the

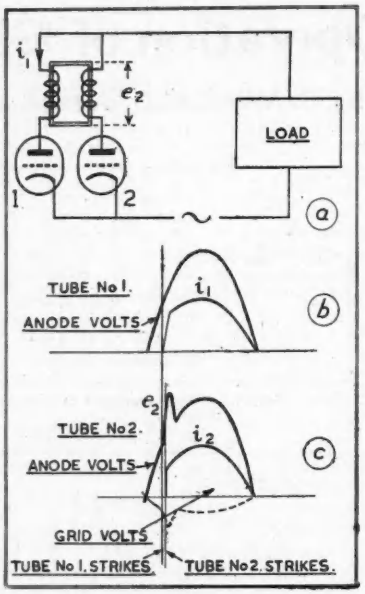


Fig. 5. Operation of inductively coupled parallel circuit.

respective anode circuits and peak values can be measured with a suitably calibrated oscillograph or a peak voltmeter of the valve type connected across a resistor of small known value in series with each anode.

Possible Solutions of Problem

Although the circuit arrangement of Fig. 4 offers improvements, it does not give the simultaneous striking which represents the ideal condition for parallel operation. There are several ways in which this condition may be attained or approached, as represented by the following classification.

1. By means of circuits in which the striking of one tube causes a sudden reduction of grid voltage so as to ensure the striking of the second tube, irrespective of the normal grid control function.

2. By using a sharply peaked grid voltage, generally in conjunction with a negative grid bias, so that both grid potentials are sharply reduced, or even made positive, at the striking point. This arrangement is already fairly well known as a means of avoiding the "softness" of control experienced with the phase-shift method when low grid voltages are used.

3. By arranging that the striking of one tube causes a sudden increase of anode voltage on the second tube so as to ensure its striking by making the critical grid voltage considerably higher than the applied grid voltage at that instant (*see* Fig. 2).

Special grid circuit arrangements as required under classifications 1 and 2 above are perhaps of limited interest as the form of grid control is to a large extent determined by the type of application. In this connexion it may be noted that the worst conditions are given by plain negative D.C. bias control, with which the second tube may not strike at all unless suitably low values of bias can be reached. The best conditions are obtained with a grid voltage having a sharp peak obtained, for example, by the charging of a condenser through a gas-discharge tube which conducts at a given point in the cycle. There are several variants of this form of circuit, which may also be arranged for phase-shift control by the usual RC or RL bridge methods so as to vary the phase position of the peak relative to the anode voltage and thus give anode current control.

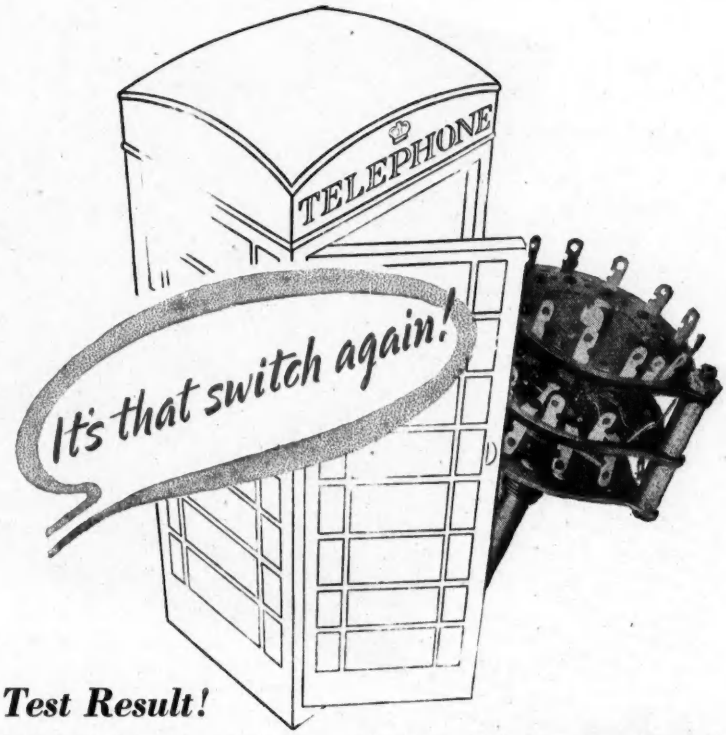
Inductive Coupling of Anodes

A circuit arrangement representative of classification 3 is shown in Fig. 5a. Two similar coils are mounted on an iron core and connected in series with the respective anodes so that each carries the anode current of one tube. The windings are arranged so that if, for example, tube No. 1 strikes first, the resulting sharp rise of current i_1 in the corresponding winding induces a voltage e_2 in the other winding, which adds to the anode voltage of tube No. 2, causing this tube to strike as already explained. Similar relations apply if tube No. 2 strikes first.

This method is similar to the phase-equaliser system used with multiphase mercury-arc rectifiers to ensure equal sharing of load between anodes and an improved transformer utilisation factor (ratio of secondary rating to D.C. output). The provision of the coupling inductor represents a complication and expense, but this may not be greater than would correspond to the use of special grid circuits in cases where they would be practicable.

The operating conditions are represented by the diagrams in Fig. 5 b and c. The sharp rise of anode current i_1 in tube No. 1 (Fig. 5b) consequent upon striking induces the pulse of

(*Concluded on page* 357)



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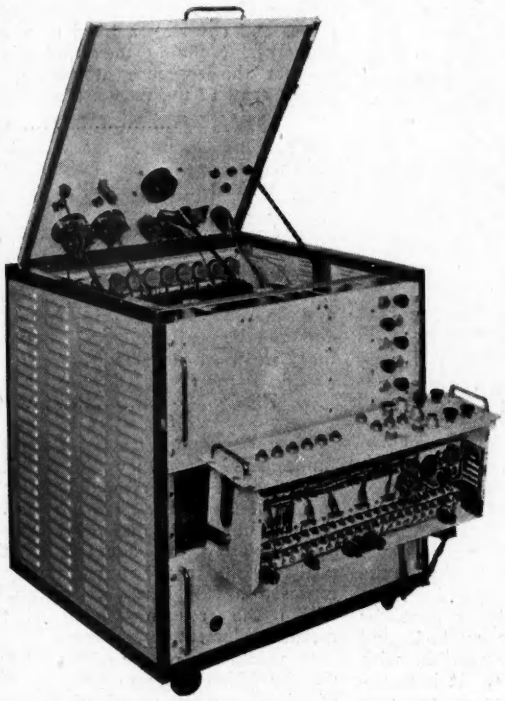


A New Electronic Analyser

By

G. R. BALDOCK, B.Sc.,

and

W. GREY WALTER, M.A.*

Fig. 9. Electronic analyser made by The Edison Swan Electric Co. Ltd., in collaboration with the authors. The back of the pre-set controls is shown on one of the units under the open lid. The main relay and averager unit has been withdrawn to show the accessibility of the components.

THE development of electronic techniques for the study of potential variations at infrasonic frequencies, chiefly vibration studies and bioelectric effects, has led to several attempts to evolve automatic low frequency analysers combining the virtues of fine frequency discrimination, rapid presentation of the analysis, and reasonable simplicity in method. Before describing these methods, it is an advantage to note a few of the graphical methods for comparison.

1. Periodic Functions

(a) The envelope method[1] is useful for waveforms containing few harmonics. Its application helps to train the observer to make rapid visual estimates of the components,[2] especially if a harmonic synthesiser[3] is available for use as a training device.

(b) Numerical methods[4, 5] yield results, the accuracy of which is dependent on the number of ordinates measured.

2. Aperiodic Waveforms

(a) The numerical methods can be modified to analyse sections of aperiodic record, but it is necessary to measure a large number of ordinates to obtain a satisfactory result. Bertrand and Lacape[6] use the method, choosing sections of record in which short bursts of periodic variations occur, and choosing the fundamental period accordingly.

(b) A more general method for dealing with aperiodic functions, in which there is no need to choose an epoch or fundamental period, is due to Bernstein.[7] It is similar to the method of superposition described by Manley.[8]

Suppose the function

$$F(t) = \Sigma A \sin \frac{2\pi}{\tau}(t + \theta) \quad \ldots\ldots\ldots \quad (1)$$

where τ has a number of values $\tau_1, \tau_2, \tau_3 \ldots \tau_n$ which are called the partial periods of the function, and are not necessarily linearly related.

Then the function

$$F_1(t) = F(t) + F(t + \frac{\tau_1}{2})$$

contains no components whose periods can be written in the form $\frac{\tau_1}{2n+1}$ where n is a positive integer.

Similarly, the function

$$F'(t) = F(t) - F(t + \tau_1)$$

contains no components whose periods can be written in the form τ_1/n.

By continued application of this process we can form a function which contains only one of the components, and so arrive at the analysis.

The values of the partial periods τ are found by the formation of the "spectral function" of $F(t)$, which is itself a function of τ. This involves measurement of ordinates and slopes and its computation occupies about the same time as the ordinary process of harmonic analysis. The advantage of the method lies in the fact that there are no limitations to the values of τ, as in the case of harmonic analysis, so that the function can be treated as the resultant of a number of components in no way related to one another. A schedule for computation by this method has been worked out and successfully applied to the analysis of electro-encephalographic waveforms.[9]

* The Burden Neurological Institute.

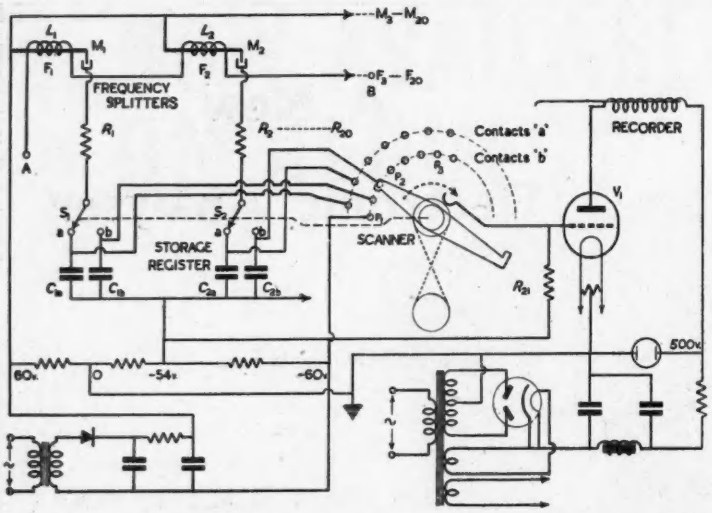


Fig. 1. Circuit of original analyser, showing change-over switch and scanning device. This was described in *Electronic Engineering*, Nov., 1943, p. 236.

Electrical Analysers

To avoid the labour involved in the arithmetical analysis, several types of electrical analysers have been devised. Here the design of the instrument must depend on the type of information which is required and the way in which it is to be presented.

In the method of Grass and Gibbs[10,11] a section of the record 30 sec. long is made into a continuous periodic waveform, reproduced at high speed and analysed with an audio-frequency analyser. This should theoretically provide an analysis as accurate as that achieved by the numerical method using about 3,000 ordinates. Its limitations are the technical difficulties of producing and scanning the variable width record and keeping the running speed constant.

An ingenious method which provides the same type of analysis as the above method is that devised by Fürth and Pringle.[12] The computation of the integrals in the straightforward Fourier analysis is performed by a heptode used as a modulator, with the complex waveform fed in at one grid and a sine wave at the frequency of the harmonic whose amplitude is required on another grid. The output of the heptode is rectified and measured with a meter, and in this way all the coefficients can be evaluated.

In many problems it is desirable to have the analysis presented immediately after the presentation of the primary record, and to have the whole of the record analysed. These requirements obviously cannot be satisfied by the above method, and they are in fact incompatible with a high resolving power. It is necessary to have a number of resonant elements, tuned to a series of set frequencies covering the range under investigation, each selecting the component at its own frequency. Suppose that one of these elements consists of a simple inductance, capacitance and resistance, in a rejector circuit tuned to a frequency f c/s. and covering a band of width $2.\Delta.f$ c/s. (defining the band width so that the response at $f \mp \Delta f$ is 44 per cent. of the response at f, *i.e.*,

$$Q = f/\Delta f \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

When the input to the circuit is switched off the oscillations will decay with a time constant,

$$t = \frac{Q}{\pi f} = \frac{1}{\pi \Delta f} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

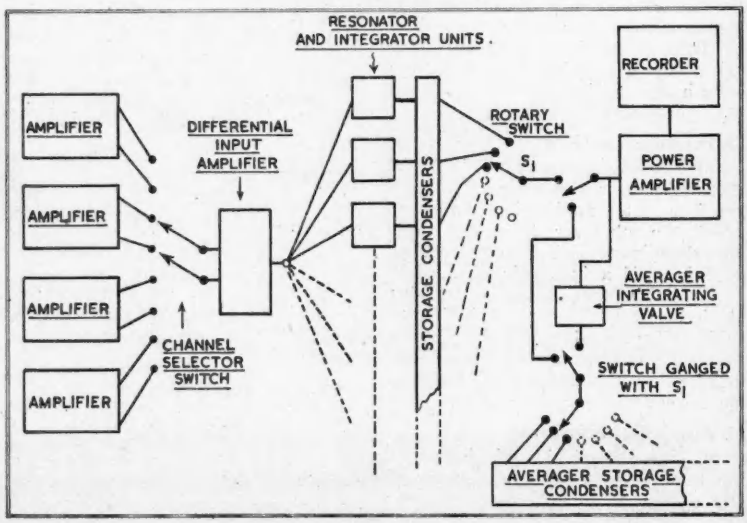
Hence if the analysis is to be carried out over a period T, in order that there should be no confusion due to the build-up and die-away time, we must stipulate

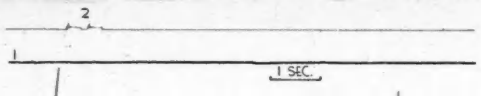
$$T >> \frac{1}{\pi \Delta f} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

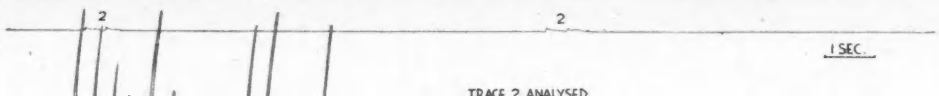
Thus we cannot treat $1/T$ as the fundamental frequency, so that the analysis will not correspond with the arithmetical result. Each recorded peak in the spectrum will represent approximately the average of the peaks in the true harmonic analysis representing the harmonics which lie within the frequency band of the resonant element.

It would be possible to construct circuits which combine the properties of high selectivity and high decrement, but each circuit would require two or more valves, and as the instrument needs at least twenty resonators to be of any use it seems better to compromise by using a simple arrangement for routine work, while

Fig. 2. Block diagram of improved analyser which can be connected to a number of amplifying channels by means of the selector switch.







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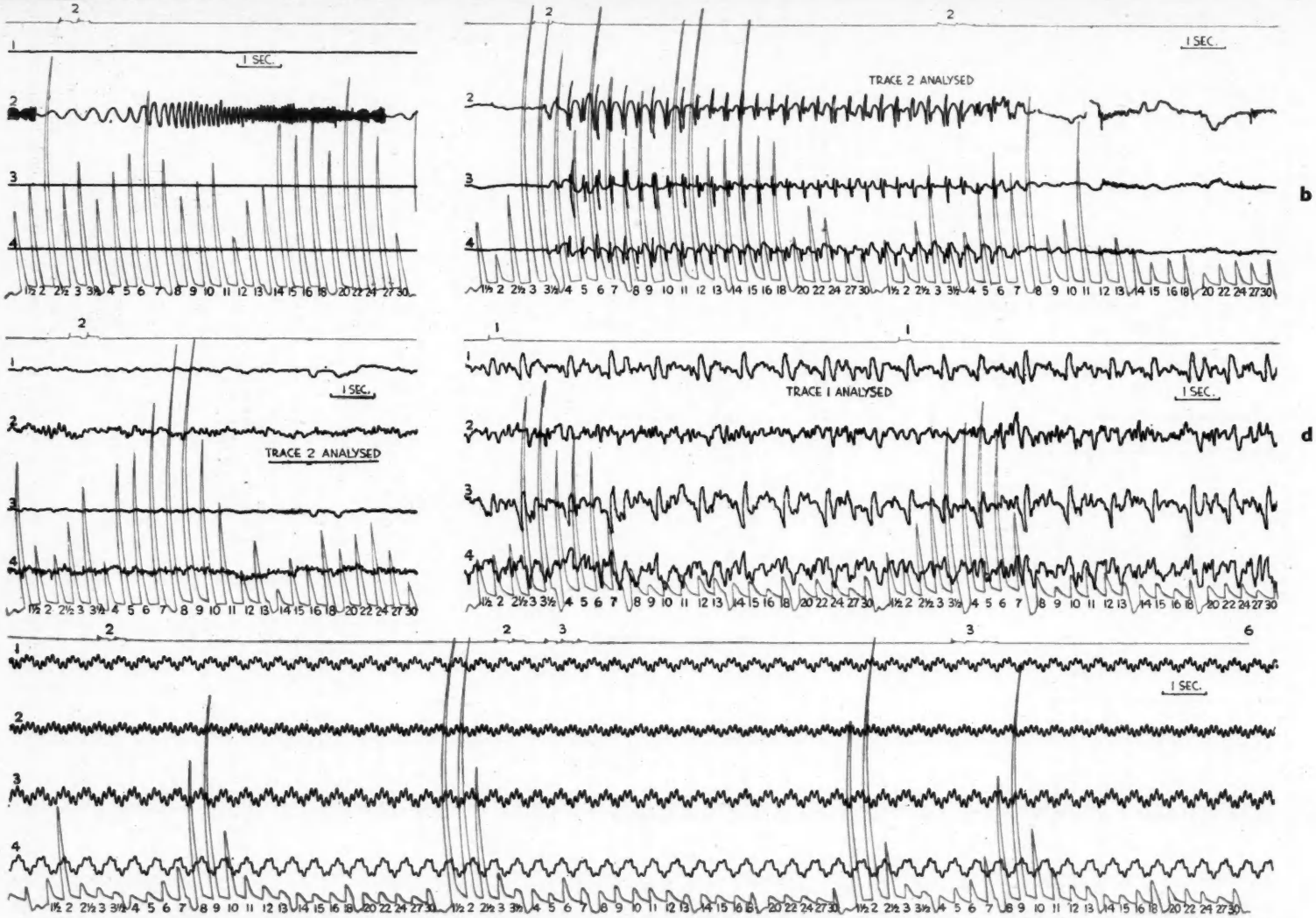


Fig. 6. Examples of typical records obtained. The original wave tracing is in black and the analysis is written on the record in red ink in a position corresponding to the part of the wave analysed. (a) Waveform of varying frequency. (b) " Wave and spike " complex waveform associated with epilepsy. Note the harmonically related peaks at 3, 6, 9, 12 and 15 c/s. (c) Analysis of normal low voltage E.E.G. record, showing the value of the analyser in revealing components which could not be determined in the original trace. (d) Complex abnormal E.E.G. record, showing a change in the dominant frequency component between two 10-second epochs. (e) Example of the use of inter-channel analysis. Channels 1 and 2 both contain components at 1½, 3½, 4, 5, 6 and 7 c/s, but the interchannel analysis contains a greater proportion of 1½ and 3½ c/s, indicating that these components are out of phase between two channels.

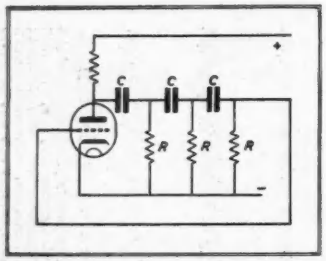


Fig. 3. Principle of the phase-shift oscillator.

particularly interesting sections of record can be analysed arithmetically or by the Grass method. The above observation applies also to the question of the incorporation of bandpass resonators.

The principle of the automatic analyser has already been described[13] and is illustrated by the circuit diagram (Fig. 1). The major modifications to the instrument are the use of frequency selective amplifiers in the place of mechanical resonators and the addition of a means for obtaining the average analysis over 1 or 2 minutes, *i.e.*, for 6 or 12 epochs of analysis. Fig. 2 shows the improved version, including the above modifications. The specifications of the 24 resonators are given in Table 1.

Resonator and Integrator

The use of tuned mechanical resonators leads to errors due to amplitude distortion, and dependence of frequency and selectivity on the amplitude of movement, and there are numerous critical mechanical adjustments which make the maintenance of the instrument tedious. Several attempts were made at constructing a low-frequency *LC* resonator, with special low-loss chokes, but in all cases it was impossible to obtain a sufficiently high selectivity.

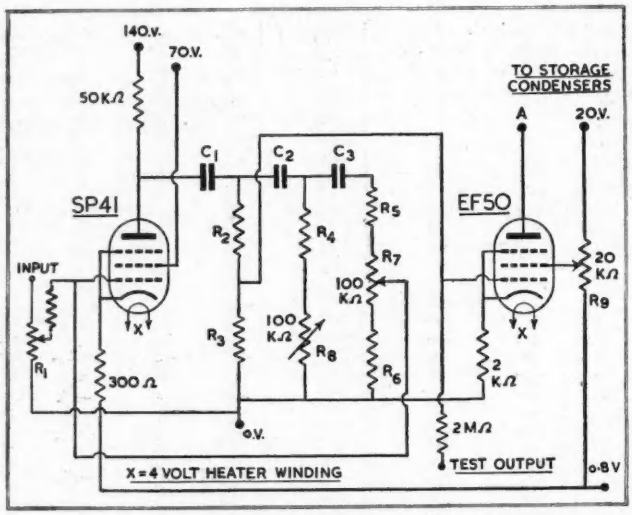


Fig. 4. The phase-shift circuit applied to the analyser for selection of a given frequency. A 2-megohm resistor is inserted in the slider to the grid to prevent change of frequency with input gain.

TABLE 1.

Frequency (c/s.)	Q	Time Constant of Decay (sec.)
1½	6	1.3
2	8	1.3
2½	10	1.3
3	12	1.3
3½	14	1.3
4	16	1.3
5	10	.64
6	12	.64
7	14	.64
8	16	.64
9	18	.64
10	20	.64
11	22	.64
12	24	.64
13	26	.64
14	28	.64
15	30	.64
16	32	.64
18	18	.32
20	20	.32
22	22	.32
24	24	.32
27	18	.21
30	20	.21

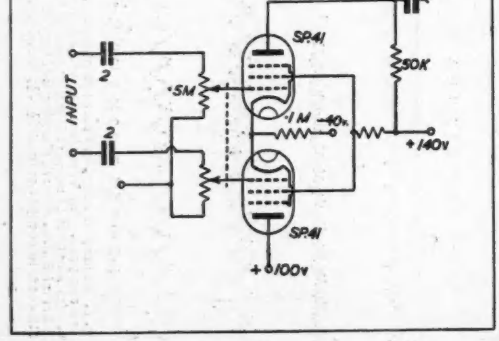


Fig. 5. Circuit of discriminating amplifier for feeding analyser circuit of Fig. 4.

Damped *RC* oscillators of the Wien Bridge and Transitron types were found to be inconvenient and difficult to adjust, and finally the circuit of a simple phase shift oscillator was adapted (Fig. 3)[14] as shown in Fig. 4. The voltage developed in the anode circuit is fed back to the grid with a phase difference depending on the values of C and R.

At one frequency only, the C-R network will produce a phase shift of 180° between the anode and grid voltages. At this frequency the valve will tend to oscillate provided that the gain is sufficient to overcome the attenuation produced by the $C.R.$ network. This gain must be of the order of 30 for oscillation to be maintained.

If, however, the amount of feedback is reduced by means of the potentiometer R_6, R_7, R_8 of Fig. 4, the system will not oscillate but will selectively amplify a signal applied to the grid.

The resonant frequency is approximately $\frac{1}{2\pi\sqrt{6}.RC}$

Where $C = C_1 = C_2 = C_3$

and $R = R_2 + R_3$

$= R_4 + R_5$

$= R_6 + R_7 + R_8$

The exact values necessary for any given frequency are best determined empirically, as their computation is tedious and involves the assumption of second order coeffic-

ients depending on the valve characteristics. The system is most stable with a cathode resistor and a small grid bias, and with this arrangement a selectivity corresponding to a Q of several thousand (where Q is defined according to Equation (2)) can be obtained without oscillation.

In order to avoid a change in impedance of any of the components on loading the network, the output is taken from the junction of R_2 and R_3, and R_3 is made low (1/10th) compared with R_2.

The output is fed to the EF.50 which acts as an integrating valve, as in the original analyser circuit of Fig. 1.

A low voltage applied to the screen through R_9 allows the valve to pass only a very low current (1.0 μA) until a signal reaches the grid from the resonating network. The anode current then fluctuates with the output of the resonator to a maximum of 30 μA, charging the associated condenser. R_7 and R_8 are used as preset fine controls for Q and frequency respectively. Twenty-four such units are mounted on one chassis and the gains are adjusted to equality by means of a preset potentiometer on the input to each unit (R_1). The inputs are connected to the output of a discriminating amplifier (Fig. 5), which is fed from the main recording amplifiers.

In the ordinary way the analyser is connected to the output from one or other of the main amplifying channels and the frequency analysis thus recorded is that of the potential variations between two electrodes to which the input of the amplifier is connected.

The analyser can, however, be connected *between* two channels in such a way that it is sensitive almost exclusively to those potential changes which are out of phase in the two channels. A local analysis is therefore possible, even where there is a large and diffuse or variable frequency component. This is useful in electroencephalography for investigating local phenomena[18], which in the primary trace are frequently obscured by in-phase potential variations common to two or more channels (*see* Fig. 6).

The storage condensers and writing-out arrangements, and the presentation of the analysis, are the same as previously described[18].

In the more recent models of the analyser an additional useful device has been added to provide an "average analysis" every minute or so. This is written out on the record in the same way as the other analyses and is equivalent to analysing the record over an epoch of one or two minutes.

In this way the variability of the analysis from time to time can be ascertained.

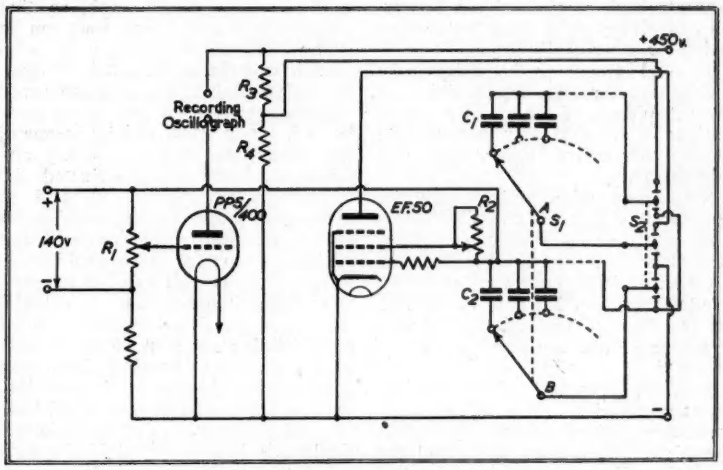


Fig. 7. Circuit diagram of the "Averager."

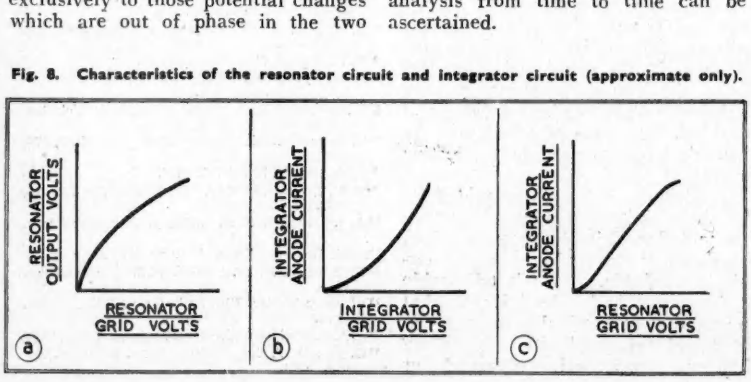
The principle of the averager is illustrated in Fig. 7. The recording pen is driven by the PP5/400, the grid of which is biased by a supply voltage of 140 so that the resting level of the recording pen can be set by means of the potentiometer R_1.

The cathode, which is normally connected to the point B when the switch S_2 is in the up position, is fed with a series of negative impulses from the storage condensers C_2 as the switch S_1 rotates (as described in the previous paper, and shown in Fig. 1).

The grid of the EF50 which is the averaging valve, is also biased on the 140 V supply, while its cathode receives the same input. The anode is connected to the point A, so that each pulse which appears is registered in the appropriate condenser of the bank C_1, which is also continuously scanned by S_1. The high tension supply for the EF50 is obtained from a potentiometer chain R_3, R_4, across the 450 V supply. After a period of six or twelve analysis epochs according to the setting of the automatic switch mechanism which controls S_2, the latter is thrown over. This causes the averager condensers C_1 to be scanned out by S_1 on to the input circuit of the PP5/400, so that the average is recorded. At the same time the ordinary analysis condenser bank C_2 is short-circuited, so that no confusion is caused in the succeeding epochs due to the condensers retaining their charge.

R_3 controls the sensitivity of the averaging circuit. The automatic switching is controlled from a

Fig. 8. Characteristics of the resonator circuit and integrator circuit (approximate only).



separate bank of S_1, and can be performed either by a Uniselector type switch or a series of relays.

In electroencephalography the averager is used for obtaining a general picture of the activity over a period of several minutes without having to measure the ordinates and add them up.

The frequencies and selectivities chosen for a particular application of the instrument are shown in Table 1. It will be seen that the longest time constant of decay occurs in the lowest band of frequencies and is 1.3 sec. In the case of the resonant circuit tuned to 30 c/s. the build-up or die-away time is only about 0.25 sec. Therefore, if the epoch is less than about 5 seconds, the lowest frequency resonators will lag seriously behind the highest frequency ones, and the analysis will be misleading. For this reason the epoch time for the analysis was not made shorter than 10 seconds.

The amplitude response of the resonator circuit is not linear (*see* Fig. 8a) but the non-linear effect can be reduced by suitably choosing the input level so that the integrator non-linearity (Fig. 8b) partially compensates for it. The overall response is then as in Fig. 8c.

It is interesting to note that if the resonator is executing free damped oscillations the decay time of the integrator current will be shorter, owing to its non-linearity, than the time measured using the resonator output. This is an advantage because the lengths of the build-up and decay times for a given selectivity are less than those calculated for a simple resonant circuit. In general it is desirable for the input voltage to be as low as possible so that the resonator valve is working on the straightest part of its characteristic. A small change of mutual conductance produces a relatively large change in the frequency and Q, so that these quantities are not entirely independent of amplitude, but the effect is least noticeable at low input levels. It was for this reason that the otherwise convenient position of the gain control in the integrator grid circuit was abandoned.

Calibration

As might be expected, the setting-up and calibration of the complete instrument requires skill and care.

A low frequency oscillator is applied to the input, and the points marked "Test Output" (Fig. 4) are connected through a 24-way switch to the input of an amplifier feeding an ink-writing oscillograph, so that the performance of each unit can be studied. A microammeter is connected from the anode of the integrating valve (A in Fig. 4) to the 140 V tapping, and the current when there is no input is set at 1μA by means of the control R_9. The frequency and selectivity are then adjusted by means of the controls R_8 and R_7 respectively, and finally the gain is set on the input potentiometer. The selectivity can be checked either by direct measurement of the response at different frequencies or by calculation from the time constant of decay of oscillations as seen on the record.

For routine calibration the output from the amplifier which is recording the resonator performance is fed back into the analyser, so that a continuous oscillation is maintained if the gain is sufficiently high. It is thus possible to see whether all the units are working satisfactorily simply by turning the 24-way switch and observing the amplitude of the oscillations, which can be compared with previous observations made when the calibration was known to be correct.

Individual Frequency Observations

The analyser treats the record as though its components were the notes of a chord lasting ten seconds, and it cannot indicate the temporal order in which these notes appeared, though it does show their mean relative amplitudes throughout the epoch. It does not distinguish between a large signal present for a short time and a smaller one present for a long time.

This ambiguity may be overcome by an additional device which is useful when the momentary fluctuations of any single component of a complex waveform are of interest. It is a simple matter to observe continuously the output of any one of the resonating circuits. Thus a meter can be connected to any of these circuits and its deflection at any moment indicates the activity at the frequency of the circuit concerned; alternatively, the output from one or more of the resonators can be amplified and recorded by one of the primary channels so as to provide a selective record.

A selector switch is provided so that the activity at any one frequency can be followed in this way. Further, a separate "roamer" resonating circuit is available. This is adjustable in frequency and selectivity so that any rhythm of particular interest can be tuned in, and its momentary changes continuously observed or recorded, even when its frequency falls between two of the pre-set frequencies, for example, at 10.5 c/s, or outside the ordinary range, for example, at 40 c/s.

Performance

Further examples of the performance of the analyser are shown in Fig. 6.

The resolving power of an analyser may be made very great, since the restriction of amplification to a narrow band of frequencies proportionately reduces the obscuring effect of basic irregularities or "noise." Thus, the smallest deflection which can be clearly recognised in the primary trace corresponds to a potential change at the input electrodes of about 5 μVp when the amplification is uniform from 0.5 to 50 c/s; when the output is passed through a selective filter such as one of the resonant circuits of the analyser, rhythmic activity with an amplitude of only 0.1 μVp can be detected quite easily through the background irregularity. The analyser therefore can be used to reveal rhythms which are very much smaller than the random background fluctuations, as well as to determine the composition of complex waveforms, and when this property is combined with inter-channel phase-discriminating analysis and the averaging mechanism, the resolution is greater than is necessary for any problem at present defined. Rhythmic components of the order of 0.01 μV can easily be measured.

An improved version of the analyser is now being made by the Edison Swan Electric Co., Ltd., a photograph of which appears in Fig. 9.

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Reflex Oscillators

Condensed from the paper by **J. R. PIERCE** in the Bell Laboratories Record Vol. XXIII No. 8.

IN electronic apparatus operating at very high frequencies, the usual negative-grid triodes, tetrodes and pentodes are often replaced by vacuum tubes in which the transit time of electrons plays a basic role. Their general principles of operation have been known for some time; one long-transit-time device, the Barkhausen oscillator, has been described in the *Bell Laboratories Record*. During the war, the laboratories have made available for military use several types of long-transit-time tubes called reflex oscillators. In certain applications these have a number of electrical and mechanical advantages over other somewhat similar devices.

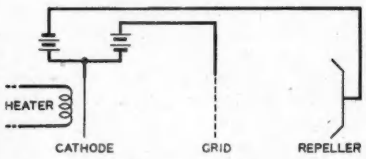


Fig. 1. Principle of reflex oscillator.

In its basic principle of operation, the reflex oscillator is simple. Consider first the arrangement shown in Fig. 1. The electrodes are assumed to be enclosed in a highly evacuated container as with a conventional triode, but the grid is positive with respect to the cathode, and the repeller, which corresponds to the plate, is negative. Electrons leaving the cathode in a steady stream will be accelerated by the grid. Some of them will be stopped by it, but others will continue through its meshes and proceed toward the repeller. Since the repeller is negative with respect to the grid, however, all of the electrons that pass through the grid will be turned back before they reach it, and will stream back steadily and pass through the grid in the opposite direction. In both directions, the flow of electrons will be uniform, and the electrons will continuously take energy from the circuit as they approach the positive grid from either direction and will give energy to the circuit as they depart from it.

Now suppose that this grid is replaced by two grids set into the top and bottom of a metal pillbox, as

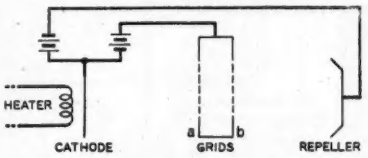


Fig. 2. Double grid to vary velocity of electrons.

indicated in Fig. 2. Electric current flowing around such a closed "cavity" or "resonator" produces an electric field between the grids, and yet there will be no field whatever outside of the resonator. The principle of such resonators is very simple. The two grids may be thought of as part of the capacitance of a resonant circuit, and the annular connexion between them made through the walls of the pillbox, which act as a single turn coil, provides the inductance. When such a resonator is used, the action of the radio-frequency field on the electron stream in the tube is confined to the short space between the two grids.

In the structure shown in Fig. 2, the accelerating effect between the cathode and grid a and the retarding effect between grid b and the repeller are the same as in the cathode-grid and grid-repeller regions of the arrangement shown in Fig. 1. In the space between the two grids, however, the oscillating electric field affects the electrons. The grids are closely spaced so that the time of passage of an electron from one to the other is a small fraction of a period of oscillation. Depending on its direction at the moment, the field will be accelerating or decelerating, and thus successive groups of electrons will be alternately speeded up and slowed down. As a result of this action of the field between the grids, the electron stream is velocity modulated, and electrons pass into the drift space between grid b and the repeller with different velocities, depending on the time in the oscillating cycle at which they pass through the field between the grids. Because of this, the period during which the electrons will remain in the drift space will vary for different electrons.

With the oscillating electric field of Fig. 2, these two effects alternate. Those electrons passing through the grid space during the interval A to B of Fig. 3 will be spaced farther apart when they return to the grid because of the increasing velocities with which they left it, while those passing through the grid space during the interval B to D will be bunched closer together on returning. The electrons returning to the grid of the tube will thus alternately be bunched and dispersed.

As the electrons pass through the grid space on their return journey, they will give energy to the oscillating circuit or absorb energy from it, depending on whether the electric field at that moment opposes or assists the electron stream, and the amount of energy transferred will depend on the density of the electron

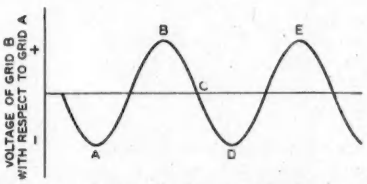


Fig. 3. R.F. voltage between grids a and b of Fig. 2, giving alternate acceleration and retardation.

stream and on the strength of the field. If the circuit conditions are so arranged that during the brief interval while a returning bunch of electrons is passing through the grid space, the field is a maximum in the opposing direction, a comparatively large amount of energy will be absorbed from the bunched electrons, far more than is transferred to electrons over the scattered section of the returning stream. As a result, pulses of energy are conveyed to the circuit at the oscillating frequency.

To have the bunches pass through the field when the field is maximum opposing, the interval between the instant an electron leaves the grids and that at which it reaches them on its return trip should be $N + \frac{3}{4}$ cycles of the oscillating frequency, where N is any integer including zero.

The degree of bunching depends in turn both on the voltage of the

repeller and on the strength of the accelerating field between the grids. With the repeller voltage set to give a drift time of $1 + \frac{3}{4}$ cycle, for example, the degree of bunching will first increase as the field strength is increased, will reach a maximum at some particular value, and then will decrease because of an effect that may be called "over-bunching."

This situation as applied to the reflex oscillator is illustrated by the curves of Fig. 4. Here, distance along the abscissa represents the voltage between grids A and B, that is, the strength of the electric field between the grids times the distance between them, and that along the ordinate represents the degree of bunching, which may also be referred to as the strength of the electron current, since greater bunching, representing a greater concentration of electrons, corresponds to a greater current. Each curve represents the relationship for one repeller voltage selected to give an optimum drift time such as $\frac{3}{4}$ cycle, $1 + \frac{3}{4}$ cycle, and so on up to $4 + \frac{3}{4}$ cycles. All the curves rise to the same maximum value since the maximum bunching is the same for all drift times, but the field or voltage required to produce maximum bunching decreases as the drift time increases. The power transferred from the electron stream to the circuit is proportional to the product of current and voltage. As the current changes slowly with voltage near the current maximum, maximum power will not occur at maximum current but at a voltage a little higher than that giving maximum bunching. Power will be greater for shorter drift times, since the voltage to produce maximum power is greater for shorter drift times and the current is the same. The solid curves of Fig. 5 represent power.

Power may be taken from the oscillating circuit by means of a coil coupling the magnetic field of the resonator of Fig. 2. Part of the power will be absorbed by the load connected to this coupled coil, and part will be absorbed by the losses in the resonator itself. The total power dissipated in load and resonator is proportional to the square of the voltage between the grids. For any given set of conditions, therefore, the total power could be represented by the dashed curve of Fig. 5.

Steady oscillation will take place at points where the dashed curve

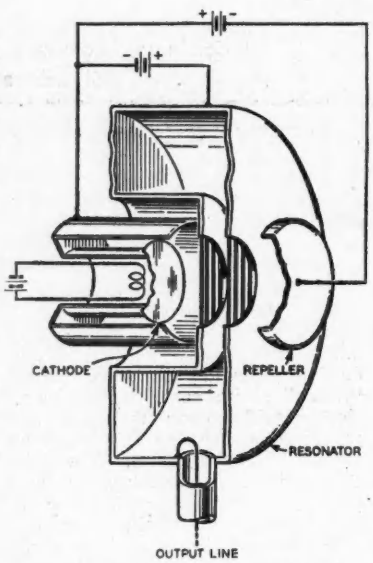


Fig. 6. Cross-sectional view of reflex oscillator.

crosses a solid curve, since at these points the output just equals the input. Maximum power will be obtained when this intersection is at the peak of one of the curves. For the conditions shown, the dashed curve never crosses the curve for $\frac{3}{4}$-cycle drift time, which means that with the load and circuit losses represented by the dashed curve, the tube would not oscillate with a repeller voltage giving a drift time of only $\frac{3}{4}$-cycle.

An important characteristic of the reflex oscillator is the electronic tuning of which it is capable. With a drift time of $N + \frac{3}{4}$ cycle, the current is in direct opposition to the electric field between the grids, and thus the effect of the electron stream can be regarded as a negative conductance shunted across the resonator. If now the repeller voltage is changed so that the drift time is no longer exactly $N + \frac{3}{4}$ cycle, the radio-frequency current is no longer in exact phase opposition to the radio-frequency voltage. The electron stream no longer produces a pure negative conductance, but rather an admittance, with a susceptance as well as a negative conductance. The susceptance tends to alter the frequency of oscillation just as would a capacitance or inductance connected across the resonator. Thus, if the repeller voltage is changed, the frequency of oscillation is also changed.

Fig. 2, used to explain the operation of the reflex oscillator, is in a highly schematised form. The actual oscillators are constructed more as shown in Fig. 6. The resonator or resonant circuit, shown as a flat pill-box in Fig. 2, is actually a re-entrant metal annulus of the form shown in Fig. 6, and the grids are stretched across circular openings in the centres of the opposite faces. At one point of the periphery of the annulus, a copper tube is connected that serves as the outer surface of a concentric conductor. The central conductor is connected to the annulus at the point where the tube is fastened, makes a single loop inside the annulus, which links the magnetic field, and then passes through the tube. It is by coupling to this loop that the output power is obtained. The actual proportioning and arrangements of the various elements, and the type of containers, vary with the particular use to which the tube is to be put.

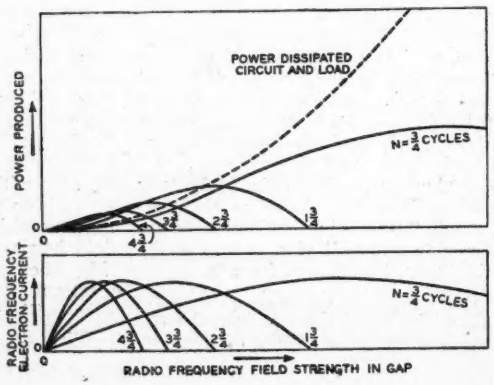
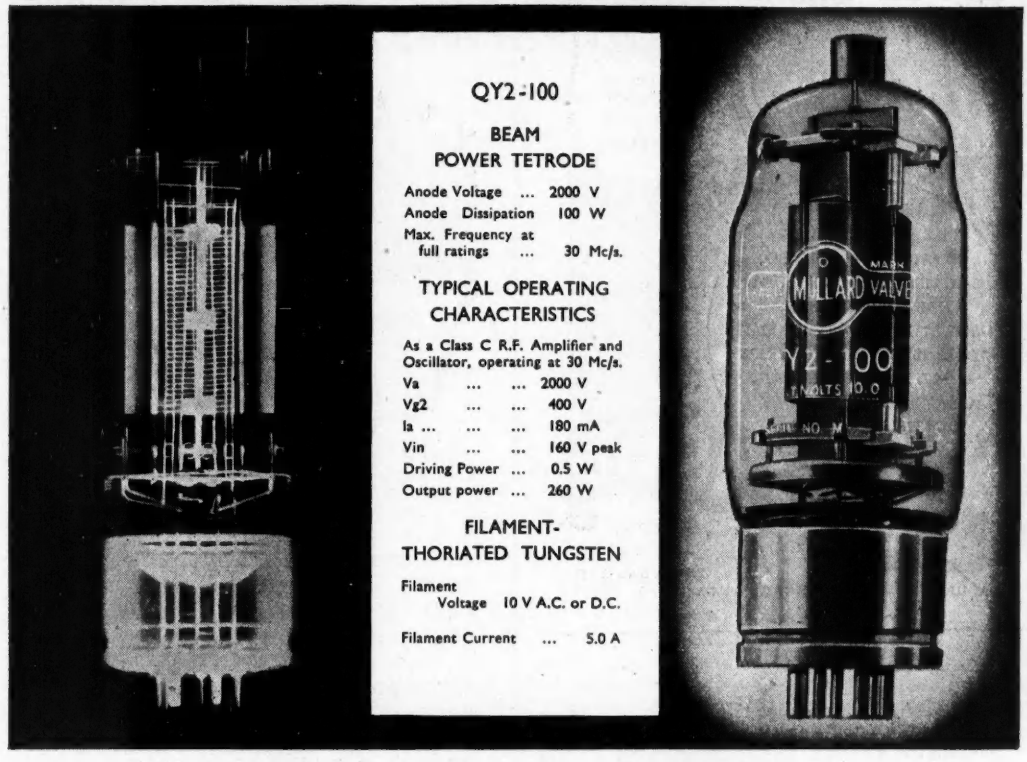


Fig. 4 (below). Relation between r.f. field in gap and r.f. current for repeller voltages giving various drift times.

Fig. 5 (above). Relation between r.f. voltage and output power for the same repeller voltages.

DEPENDABILITY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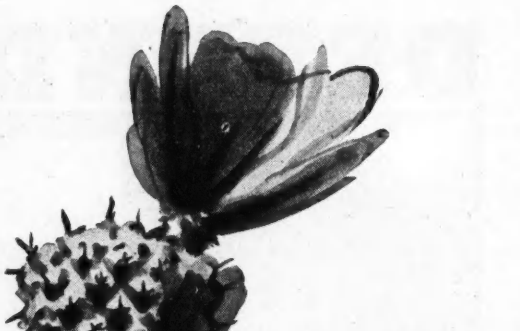

There's a moral in the ECHINOCACTUS NAPINUS CHILE . . .

. . . a moral in so far that if you don't know anything about cacti and start messing about with them you are liable to get stung rather badly.

Now apply the same thought to Transformers; some people want a few Transformers and think the order is not large enough to bother us with (nonsense of course, as you know, but some people do think that) so they knock a few up themselves from odds and ends that are lying about.

Of course, the so called Transformers are just not quite perfect and don't just do the job they should. The same thought applies also to very cheap quality Transformers which some people buy and attempt to use.

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A D.C. Amplifier Using a Modulated Carrier System

By R. A. LAMPITT, A.M.Brit.I.R.E.*

THE problem of amplifying small voltage changes at frequencies below 1 c/s. has always been a difficult one. It often becomes necessary to amplify very slow changes in addition to possible transients or continuous changes at frequencies up to several thousands of cycles/second.

Amplifiers have been designed to handle these very low frequencies and to have gains of anything up to a million. These amplifiers are generally of the direct coupled type, the type which has the normal coupling condenser removed so that the positive anode voltage of the first valve appears on the grid of the valve following it. In order to compensate for this, so that the second valve operates under normal conditions, its cathode potential must be raised above earth also by an equal amount to the positive grid voltage plus the amount of the necessary bias.

By the time this has been done to several stages, the required H.T. line voltage becomes very high. This is a disadvantage, of course, but on the other hand it may be tolerated providing the results are otherwise satisfactory.

Owing to the fact that the interstage coupling is direct, any slight change in H.T. voltage will obviously cause a change in the grid potential of the second valve in the amplifier. This will be amplified, with the result that the output voltage may drift by a very large amount, sometimes a hundred volts or more, depending upon the overall gain of the amplifier.

This means that the H.T. supply must be stabilised, and if the amplifier is to work with signals of, say, 1 mV, the drift in H.T. voltage must be 1 mV at the most. As a percentage of a supply of, say, 500 volts, this is 0.0002 per cent. The heater current must also be stabilised very efficiently and as a result the apparatus becomes more involved.

After having stabilised both supplies, there still exists a very pronounced zero drift if the gain of the amplifier is very high. This appears to be due to actual emission changes in the first one or two stages, and may be accentuated if the valves are situated in any draught. These changes are very small indeed, but in actual practice, if high gains are used these changes appear as voltage output changes of 20 volts or more.

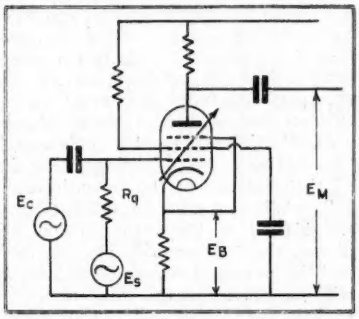
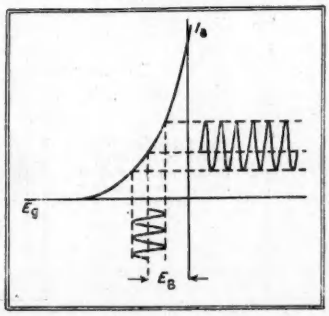


Fig. 1. Modulation by injection of signal in grid circuit.

In order to overcome this effect on zero drift, many special circuits have been designed, all of which make use of an automatic balancing network. Some rely on the possibility of two similar valves changing in exactly the same way, so that their voltage drifts may be made to neutralise each other, while others make use of a special twin triode with a common cathode connected so that the drift of one section operating as the amplifier is counterbalanced by the effect of the other element which is used for balancing only.

Fig. 2. Distortion due to non-linear characteristic.



The Modulated Carrier System

In order to eliminate all or most of these disadvantages the author has recently designed an amplifier in which the signal modulates an R.F. carrier wave. It was realised that when transmitting a signal in the ordinary way, the carrier may be modulated at any frequency from zero up to a value which is only limited by the frequency of the carrier itself. When this modulated carrier is received it is amplified and rectified, the voltages at the modulation frequency appearing across the diode load being an exact replica of the modulation of the carrier right down to zero frequency. The modulated carrier could then be amplified to a great extent by means of an ordinary A.C. amplifier and the resultant then rectified.

The great advantage of this method is that it is not necessary to use abnormally high H.T. voltages as before. In addition, a large amount of stabilising is unnecessary; the heater supply need not be stabilised at all and the H.T. supply only to a reasonable degree.

Experiments were carried out with the object of developing 50-volt D.C. changes for D.C. voltage changes of 1 mV. These 1-mV changes were produced by a thermo-couple of the type used in a pyrometer, and obviously these were very slow. The 50-volt changes of output voltage were to be used as a variable bias on a 3-phase mercury arc rectifier with the object of controlling its output. The whole D.C. amplifier, then, would need to have a gain of 50,000, so with this in mind an A.C. amplifier complete with output rectifier was designed. In addition to this, a special modulating circuit was devised to modulate the carrier with the slow voltage changes to be amplified.

The amplifier proved very successful in that an overall gain of 100,000

* late R.G.D. Laboratory

was obtained, and also D.C. output voltage changes of up to 1,200 were developed with input changes of 0.01 volt D.C. The small amount of zero drift was corrected by means of a constant voltage transformer in the power lead of the amplifier, and no further stabilising was required.

The Modulator Unit

If a carrier frequency of, say, 20 kc/s. is used, modulation may be done in one of several ways. Firstly, a variable-mu pentode may be employed in the first stage of the carrier amplifier, and the gain may be varied by varying the bias on the valve. If, then, the D.C. voltage changes which it is desired to amplify (hence called the signal), are made to vary the bias, the carrier will become modulated by these changes. Fig. 1 shows a simple circuit whereby the signal voltage E_s is injected into the earthy end of the grid resistor R_g. The unmodulated carrier of 20 kc/s. is shown as E_c and the modulated carrier as E_m.

If maximum gain is required it becomes necessary to adjust the standing bias E_B so that the valve is operating on the steep part of its characteristic (Fig. 2). It is obvious that as the valve characteristic is variable-mu, the modulation of the carrier will not be linear, the distortion being more pronounced as E_s increases. Another disadvantage is that for small values of E_s the percentage modulation is only small and the rest of the amplifier will be handling unnecessarily large voltages. This necessitates the use of valves with a long grid base and as a result more stages will be required for a given overall gain.

Balancing

In order to overcome this second disadvantage two similar valves may be used in a push-pull circuit as shown in Fig. 3. The carrier is fed through a phase splitter to the grids of V_1 and V_2 so that the grid voltages are equal in amplitude but opposite in phase. The two anodes are connected together through two 1 megohm resistors in series, thus R_1, R_2, R_3, and R_4 form the arms of a Wheatstone bridge. When E_s is zero, E_m and E may be made equal in amplitude by adjusting the gain of V_1 by means of the potentiometer VR_1. When these two voltages are equal (and as they are 180° out of phase) the bridge will be balanced and the voltage between X and earth will be zero. If the gain of V_1 is varied, the bridge will become unbalanced and a voltage will appear between X and earth, its amplitude depending upon the degree of "off balance," *i.e.*, to half the difference between E_m and E.

$$E_{mo} = E - \frac{E_m + E}{2}$$

From this it is seen that a voltage appears between X and earth whenever the bridge is off balance, and that the amplitude is determined by the difference between E_m and E. The fact that E_m may be either greater or smaller than E is not important except where the phase of E_{mo} is concerned, *e.g.*, if E_m is greater than E, the phase of E_{mo} will be the same as E_m and vice versa.

If the bridge is first balanced, a D.C. signal E_s may be applied, and as a result a voltage whose amplitude is proportional to E_s will appear across R_5. So long as E_s is unidirectional, the modulation envelope of E_{mo} will be an amplified version of this signal (Fig. 4 (a) and (b)).

If, however, E_s is an alternating voltage of low frequency, the carrier will appear as in Fig. 4 (d). In order to correct this, therefore, it is necessary to off-set the bridge a little so that the signal modulates the carrier to approximately 100 per cent. (Fig. 4 (e)).

The amplification of the circuit shown is equal to half of the stage gain of V_1, and as V_1 is a pentode, a gain of about 50 may be reasonably expected. A number of stages of amplification may be added in order to increase the gain to that required, and the output can then be rectified and filtered in order to obtain the amplified signal voltages only.

Class B Operation

As has been mentioned, if E_s becomes large, distortion will occur due to non-linearity of the valve characteristics. This may be overcome in the following manner:

Two "straight-mu" pentodes may be used for V_1 and V_2 and these must be biased to approximately cut-off. These two valves will, of course, rectify the carrier and as a result a large percentage of 2nd harmonic will appear in E_m and E. Due to this, a true zero will not be obtained

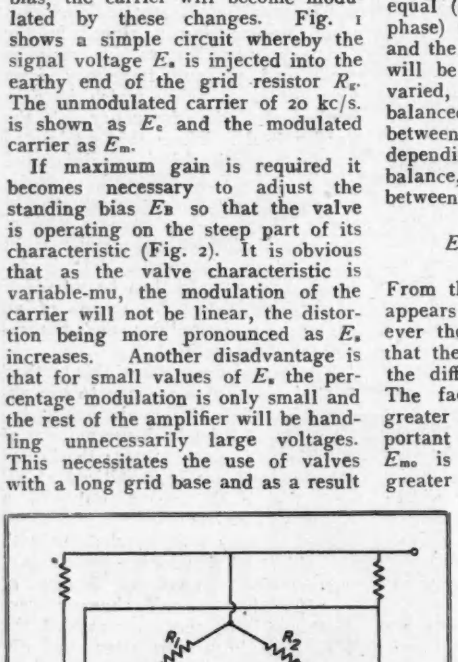


Fig. 3 (left). Use of push-pull circuit in form of balanced bridge, the output appearing between X and earth.

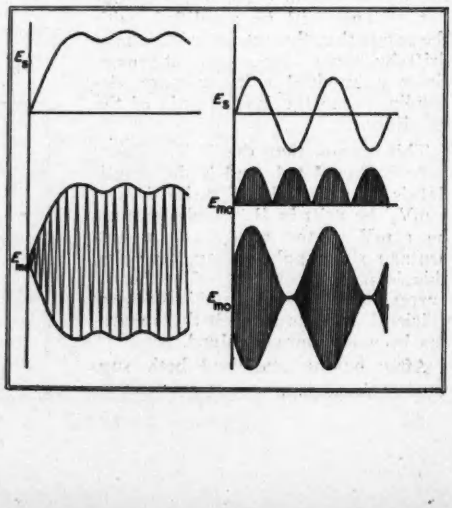


Fig. 4 (right). Effect of applying D.C. and A.C. signals to bridge circuit.

between X and earth since, although the fundamental frequencies will cancel, the even harmonics will not. The harmonic content may be reduced to a very small value, however, by the use of two tuned circuits in place of R_1 and R_2 of Fig. 3. These must, of course, be tuned to the fundamental, and, if necessary, further attenuation of the harmonics may be obtained by mans of a suitable harmonic or low-pass filter connected in the output.

Fig. 5 shows a modified arrangement of the circuit of Fig. 3. One tuned circuit only is used and the anodes of V_1 and V_2 are now joined together, so that the two valves are operating in Class B push-push. By using a load common to both valves the sensitivity of the circuit is increased, and as a result the overall gain of the apparatus will be greater.

This particular arrangement was used in the final apparatus, and it was found that although C_1 and C_2 were equal and R_{g1} equalled R_{g2}, it was impossible to obtain a true zero for E_{mo} when balancing. This was due to the fact that the impedance of the signal source changed the phase of the input to V_1 relative to that to V_2. In order to compensate for this, the resistance of R_{g2} was made much larger than that of R_{g1}, and in addition was made variable so that by adjusting it, the phase relationship between the two input voltages could be made exactly 180°.

By doing this, it was found that the harmonic content was about 1 or 2 per cent., and by the use of a suitable

Fig. 5. Modified bridge circuit with valves operating in Class B with common load

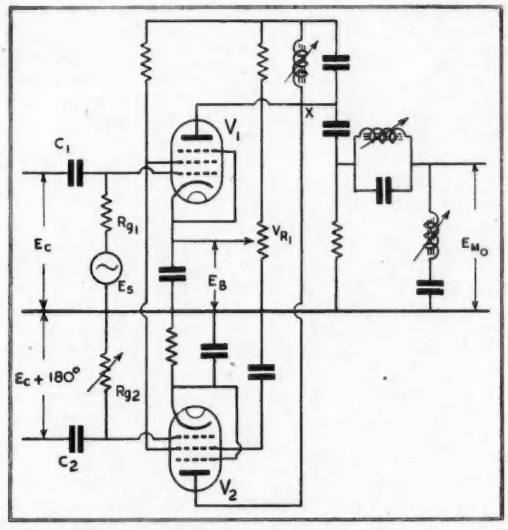
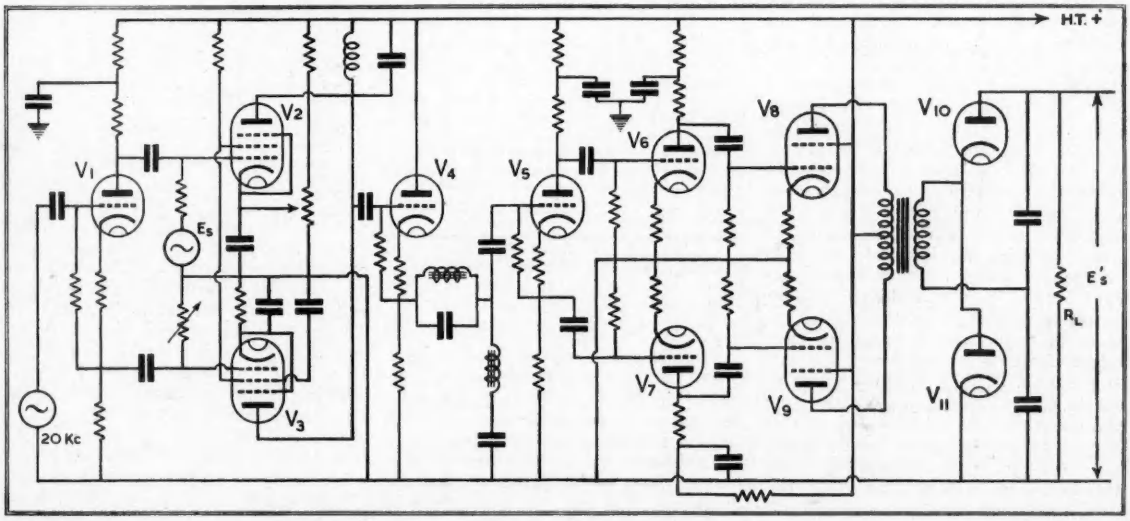


Fig. 6 (below). Complete circuit diagram.

filter this content was reduced to a very low level. Balancing was achieved by connecting a C.R.O. (through its amplifiers) to the output of the filter and adjusting R_{R1} and R_{g2} alternately until an absolute minimum was obtained. A D.C. signal of approximately 0.01 volt was then applied to check for correct operation, after which the A.C. amplifier and rectifier were connected.

Fig. 6 shows the circuit diagram of the main part of the apparatus developed by the author. The final apparatus contained its own power pack and 20 kc/s. oscillator. The oscillator was of the resistance tuned type and was mounted on a small chassis together with the phase splitter V_3, V_5, V_8, and the cathode follower V_4. The whole of this unit was completely self-contained and screened. The heaters on this chassis were fed from a 4-volt accumulator in order to reduce the slight amount of 50-cycle hum. This appeared in the output as a slight residual D.C. even when the circuit was correctly balanced, but by the use of D.C. for the heaters this was entirely eliminated.

The cathode follower V_4 was used in order to decrease the impedance between the input to the main ampli-



fier and earth so that the possibility of noise pick-up here was eliminated. Between V_4 and V_5, in Fig. 6, appears the second harmonic filter. Following this is another phase splitter driving the push-pull amplifier consisting of V_6 to V_9 inclusive, the output from which is fed through a 1:1 ratio transformer into a voltage doubler rectifier. The voltage which appears across the load R_1 is an amplified replica of the signal E_s.

As the output circuit is a high impedance one, very little current can be drawn from it, but in cases where voltage changes only are required, this arrangement appears to be quite satisfactory.

Applications

In addition to the application mentioned above, this type of D.C. amplifier was used, after slight modification, in conjunction with strain gauge apparatus for the measurement of the distortion, under load, of various parts of aircraft.

It was most suitable for the measurement of the velocity of large movable parts, such as gun turrets, etc., when in operation. The motion of the turret around its mounting was made to produce a small D.C. voltage whose magnitude was proportional to the velocity of the turret. This D.C. voltage was applied to the input of the D.C. amplifier just described. The output from the amplifier was not rectified in this case, but the modulated carrier was applied to the Y plates of a C.R.O. The time base was switched off, and a special camera was fitted to the front of the tube. This camera continuously exposed a slowly horizontally moving film, so that a record was made of the velocity of the turret at any instant after starting. The width of the dark band on the negative was a direct indication of the velocity at any instant, and the slope of the curve of the modulation envelope, an indication of the acceleration. Records of this type are very useful where possible transients are to be measured in addition to slow changes of D.C. potential.

Another possible application seems to be in conjunction with the electroencephalograph—the instrument for measuring low-frequency brain potentials.

It is most convenient to design this type of D.C. amplifier for low signal frequencies of from zero to about 5,000 c/s., so that a carrier frequency of from 20 to 50 kc/s. may be used, and, in consequence, the carrier amplifier may be of the aperiodic type. For wider ranges of signal frequencies, and R.F. carrier would become essential, and the whole apparatus would need to be thoroughly screened in order to avoid instability, etc. Since the majority of applications, however, are for the amplification of signals where the upper limit of frequency extends only into hundreds of c/s., the apparatus described appears admirable.

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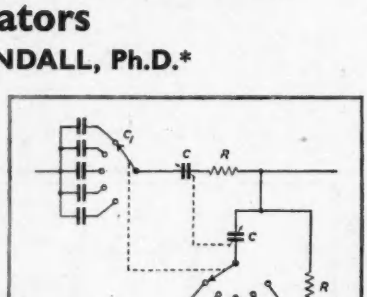
Increment Features on Variable Oscillators

By A. R. A. RENDALL, Ph.D.*

ON continuously variable oscillators, such as a heterodyne frequency type, it has been found very useful to include an increment dial whereby specific increments in frequency can be obtained at any setting of the main dial. This feature does not seem to have been included in continuously variable resistance-capacity oscillators although, of course, it is an essential feature of the Decade type of resistance-capacity oscillator. Where air condensers are used to vary the phase angle of a resistance-capacity feedback circuit in order to give an infinitely variable frequency change the increment feature may still be included by adding in series with the variable condenser, steps of fixed capacity, and for each range of the oscillator these steps will correspond to true frequency increments. This can be seen readily from the equations. In all *R.-C.* oscillators the frequency depends upon the value of one or more capacity and resistance elements, and the frequency can be expressed as follows:



$$f_o = \frac{1}{2\pi RC}$$

This frequency is the point where some critical phase relation is obtained in *R.-C.* sections which may be zero or π, but whichever it is the critical frequency can be expressed in the above form. An example of one such arrangement is shown in the diagram. The effect of connecting in series with the infinitely variable condenser C, some fixed condenser C_1 is to change f_o to f_1, where:

$$f_1 = \frac{C + C_1}{2\pi RC\,C_1}$$

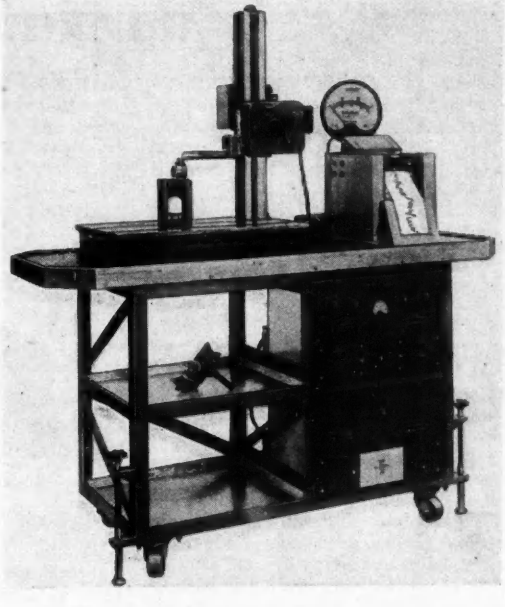
$$\therefore f_1 - f_o = \frac{1}{2\pi RC_1}$$

The increment of frequency is therefore independent of the setting of the infinitely variable condenser C. If the resistance R is changed in order to obtain ranges, as is usually the case in *R.-C.* oscillators then, of course, a different increment is obtained for each range, but this is frequently convenient. For example, suppose the frequency scale is divided into 3 ranges: 20-200 c/s., 200-2,000 c/s., and 2,000-20,000 c/s., and the increments can be arranged in each range as 0.2 c/s., 2 c/s., and 20 c/s. As many increments as is desired can be arranged by providing the required values of C_1. For example, a total of 10 may be desired and the oscillator can then be calibrated with an increment dial of ± 5 discrete increments. For the frequency ranges indicated in the lower range, we should get: 5 increments of ± 0.2 c/s. in the middle range, 5 of ± 2 c/s. top range, 5 increments of ± 20 c/s.

The above arrangement is the subject of a B.B.C. patent application.

* Lines Dept., British Broadcasting Corpn.

The "Talysurf" Surface Meter



View of Surface Meter on stand with indicating instrument and recording chart.

THE "Talysurf" Surface Meter is a stylus-type of instrument for measuring the texture of surfaces. It provides both a graph showing a cross-section of the surface, and a number representing the average height of the texture.

The instrument is suitable for the measurement of all irregularities whose spacing lies in the range between about 0.0002 in. and 0.1 in. This range is found to cover the texture normally associated with grinding, fine turning and milling, and the fine-finishing processes like honing and lapping.

A pick-up unit having a sharply pointed stylus is traversed across the surface by means of a motor-driven unit. The up-and-down movements of the stylus as it rides over the surface are converted into a correspondingly varying electric current, which is amplified and then applied to one or the other of two measuring instruments. One of these instruments is the recorder, which provides a graph drawn on paper, representing the geometrical shape of a cross-section of the surface undulations. The other instrument is the average meter, which gives the number representing the average value of the undulations.

The magnification of the height of the undulations can be varied in steps over a very wide range. The standard self-contained magnifications are from 2,000 to 40,000, but by means of accessories the range can be extended down to 400 and up to 100,000. In the direction along the length of the surface the magnification is 200 or 50.

A feature of the instrument is the ease with which the magnification can be checked by the user, starting from a pair of slip gauges.

The diamond measuring stylus has a radius at the tip of 0.0001 in. It rests on the surface with a pressure of about 0.1 gramme, which is light enough to ensure that the shape of even the softest metallic surface is not altered by the passage of the stylus.

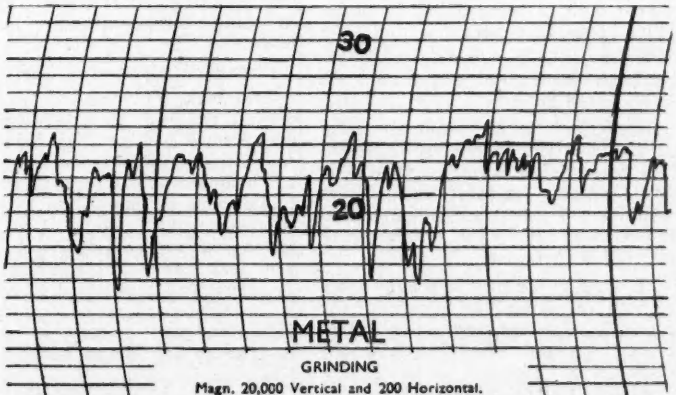
The instrument is designed to measure a wide range of parts and surfaces; and provision has been made for the development and attachment of different pick-ups and accessories for dealing with special problems that lie outside the scope of the standard instrument.

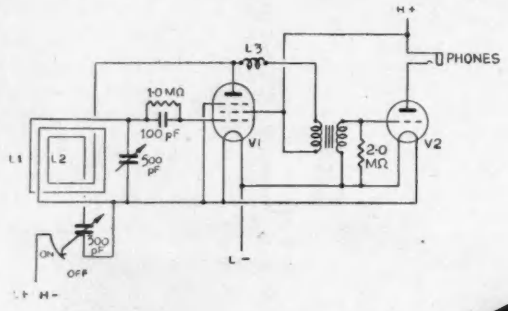
The standard pick-up will measure the roughness of external flat and cylindrical surfaces, and will enter $\frac{3}{8}$ in. diameter holes to a depth of $\frac{1}{2}$ in., $1\frac{1}{4}$ in. diameter holes to a depth of 6 in., and 4 in. diameter holes to a depth of 8 in.

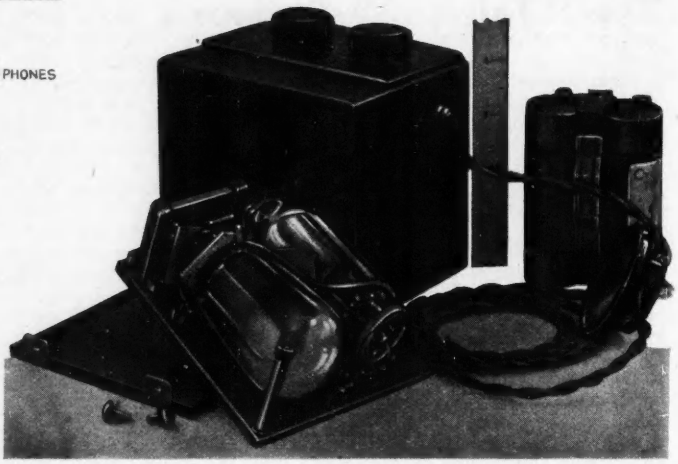
The instrument is unaffected by voltage changes in the A.C. mains, and by most kinds of floor vibration. It is suitable for research or inspection (particularly on a quality control basis) and is mounted on castors so that it can be wheeled about the laboratory or workshop to the machine whose performance is to be watched.

The "Talysurf" is manufactured by Messrs. Taylor, Taylor, & Hobson, Ltd., and full information can be obtained from them at 150 Holborn, London, E.C.1, or from the Stourton Street Works, Leicester.

Portion of typical record obtained on testing a ground metal surface.







A Home-made Midget Receiver

By L. G. WOOLLETT

THE following is a description of a home-constructed midget receiver. It employs an internal frame aerial, uses ordinary battery-type valves and is internally powered. Excluding the thickness of two $\frac{3}{8}$ in. knobs, its dimensions are $4\frac{5}{8}$ in. × $4\frac{1}{8}$ in. × $3\frac{3}{4}$ in.

The valves used are 210SPT and PM252 with their filaments connected in parallel and supplied from a 2-volt block-type cycle accumulator, a replacement for a type 800 battery.

H.T. is obtained from four fountain pen-type batteries. As the current drain is only 0.9 mA (210SPT-0.25 mA and PM252-0.65 mA), it was anticipated that it would be possible to obtain the equivalent of shelf life from the batteries. This has proved to be the case because the set has had considerable use for over a year both as receiver and unmodulated signal generator, and the original batteries are still in service.

The frequency range is from 1,230 kc/s. to 588 kc/s.

The circuit is conventional, being of the 2-valve, transformer-coupled, detector and L.F. amplifier type. The aerial winding (24 turns) and reaction winding (12 turns) are wound round the wooden case, the whole being covered with rexine.

In order to conserve space the bases of both valves and the top cap of the 210SPT were removed, the valves being soldered directly into the circuit.

Bakelite dielectric condensers are used for both tuning and reaction, and the reaction condenser is provided with a wiping contact for on-off switching.

Telephony signals sufficiently loud to be audible up to a distance of 20 ft. from the single earpiece are obtainable from the local transmitters. About eight stations have been received after dark.

The receiver is extremely stable in operation and when set to a station may be quite roughly handled without detuning or falling into oscillation. Hand capacity effects are almost entirely absent, due presumably to the use of the frame aerial, there being no H.F. points external to the set.

The high sensitivity, despite the use of the frame aerial, is attributable to the use of the pentode as detector.

It was found that 9 V H.T. was the absolute minimum for satisfactory operation, so 12 V were adopted to allow for deterioration of the battery.

Circuit details:

Grid leak, 1.0 megohm; grid condenser, 100 μF. 5 : 1 mumetal-cored transformer not parallel fed as the *Ia* of the 210SPT is only 0.25 mA. 2.0 megohm across secondary of the transformer to smooth out a peak in its response at 2.4 kc/s. Grid of detector returned to positive L.T. via grid leak and aerial winding. Grid of output triode returned to negative L.T. *via* secondary of transformer. H.T. negative connected to L.T. positive to provide an extra 2 V for Eb.

The H.F. choke being about $\frac{3}{4}$ in. diameter and having a hole of about $\frac{1}{4}$ in. fits snugly over the exhaust tube of the PM252, thus saving considerable space. It is wound with 44SWG D.S.C. and contains approximately 400 turns.

Experimental Stress Analysis Group

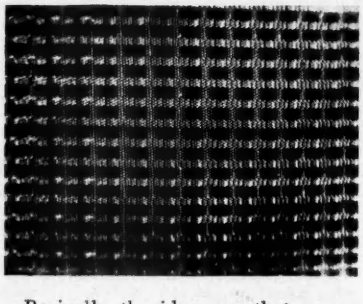
A meeting was held at University College, London, on September 6, 1946, to discuss the formation of a society concerning itself with photo-elasticity. It was decided to extend the scope to other techniques of experimental stress analysis and to form an informal group whose object will be the interchange of knowledge and experience among its members. Some of the research workers had suggested that the group should be part of the Institute of Physics rather than form a new society. The secretary of the Institute, who was present by invitation, stated that his Board was always prepared to give sympathetic consideration to requests from informal groups interested in Applied Physics, for a little assistance in the inaugural period, and that this could be accepted without prejudice to the ultimate decision. It was therefore agreed to leave the constitution open for the present and, in the meantime, to make a formal request to the Institute for temporary assistance.

Any research workers or others who are interested in experimental stress analysis are invited to communicate with the honorary secretary, Mr. E. K. Frankl, Engineering Laboratory, Cambridge.

CORRESPONDENCE

C.R. Tube Quality Test

DEAR SIR,—We have read with great interest the article by A. M. Spooner on "C.R. Tube Quality Measuring Apparatus" on page 273 of the September issue of ELECTRONIC ENGINEERING, and while expressing our appreciation of this article we would like to mention that we ourselves developed a similar piece of equipment which was exhibited on the stand of Messrs. Marconi-Ekco Instruments, Ltd., at the 1939 Radiolympia display.* As our instrument went even further than the one described in the article, in that it provided a very critical test of interlacing, we think readers may be interested to have brief details of it.



Basically the idea was that a synthetic complete television wave-form should be injected into the receiver, the vision modulation being such that on the screen of a good receiver, a lattice pattern made up of dots should appear. Each dot was of approximately element duration and separated from the next in the line scan direction by an equal space. This sequence was repeated for about four lines of the first scan of the interlaced picture and was then changed so that after the first four dots in the line, a blank period of similar duration occurred during which no dots were formed (*see* photograph). The second scan of the interlaced picture repeated this pattern but with the dots falling immediately below the spaces between the dots of the previous scan.

The resultant pattern consisted of vertical and horizontal bars of dots separated from each other by equal spaces, and the regularity in spacing of these bars formed a criterion of the linearity of the scans in the vertical and horizontal directions.

Correct interlacing was shown by the dots appearing to the eye to form a regular diagonal pattern of straight lines, this psychological effect being very sensitive to faulty intermesning of the two patterns. Other distortions and aberrations were, of course, equally evident, such as pincushion distortion or defocusing.

The photograph gives a general idea of the results obtained.

Yours faithfully,
P. L. F. JONES.

Scophony, Ltd.

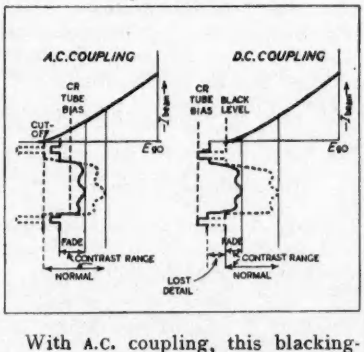
* Patent Specification No. 520,349.

Television Fading

DEAR SIR,—The following point may be of interest to readers on the fringe of the reliable reception area around Alexandra Palace.

During recent tests near Oxford it was noticed that airplanes up to 5 miles away crossing the transmission path caused the signal strength to fluctuate from relatively zero (so far as picture quality is concerned) to a little above normal level. This is assumed to be due to the reflected signal reaching an amplitude nearly equal to that of the ground wave and varying in phase.

With D.C. coupling to the C.R. tube the picture almost disappeared at times during the fades owing to the fact that the peak whites sink towards black level, leaving only the highlights to produce beam current.



With A.C. coupling, this blacking-out cannot occur: all that can take place is a loss in contrast, as with fades the black level becomes less black and the whites less white. Under most conditions at the time of the test, this proved more tolerable than a picture tending to "black-out." In the case of average fades, which were clearly obvious with D.C. coupling on the tube, they were hardly detectable with A.C. coupling.

A.G.C. is probably a better remedy, but this very much simpler modification provides an economical compromise.

Yours faithfully,
G. T. CLACK.

Balham, S.W.12.

TELEVISION COMMENTARY

TELEVISION programmes have now got into their stride and offer regular appointments to varied tastes. Sunday afternoon, if not a Children's Hour, has, at any rate, a children's corner, and Sunday evening is the playgoer's—I almost said "corner," because, excellent as the plays are, they do not always escape from the constriction of the studio set. Where film is interpolated, as for the sea shots in "Don Juan" (October 13 and 16), there is an immense feeling of expansion, and the possibilities of this heightening of atmosphere in plays is unlimited. On Thursday evenings "Picture Page" is everybody's lucky dip, and the soloists in "Music Makers" never fail to be successful picture makers also. Mr. Streeter straightens out our gardening on Saturday afternoons while we are on the way to an outside broadcast which all depends on the weather. The Ascot Meeting (October 12) won itself flattering headlines in at least one newspaper in spite of the very bad light.

Many viewers would greatly appreciate a series of simple explanatory talks by television experts on the more obvious technical defects of the television picture and the possibilities of overcoming them. Viewers are often uncertain when defects are in their own receivers and when they are a part of the transmission. But they understand that the B.B.C. admits defects. Such talks might cover the rather frequent breakdowns "Owing to technical trouble"; the necessity for frequent readjustment by the viewer of brightness control; alterations, which appear to come from the transmitting end, of the light and shade of the picture; the white flare which sometimes appears at the bottom of the picture; and similar topics which the amateur would like to understand.

JEAN BARTLETT

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NOVEMBER MEETINGS

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Radio Section

Date: November 6. Time: 5.30 p.m.
Lecture: "The Pulse Testing of Wide-Band Networks."
By: D. C. Espley, D.Eng., E. C. Cherry, M.Sc., and M. M. Levy.

Date: November 20. Time: 5.30 p.m.
Lecture: "The Voltage Characteristics of Polythene Cables."
By: R. Davis, M.Sc., A. E. W. Austen, Ph.D., B.Sc., and Prof. Willis Jackson, D.Sc., D.Phil.

Date: November 26. Time: 5.30 p.m.
Discussion on "The Economics and Subjective Requirements of Television Picture Sizes."
Opened by D. C. Birkinshaw, M.B.E., M.A.
Note: This meeting is also open to members of The Television Society, by kind invitation of the Institution.

The Secretary, I.E.E., Savoy Place, London, W.C.2.

Cambridge and District Group

Date: November 19. Time: 6 p.m.
Held at: The Cambridgeshire Technical College.
Lecture: "Radar Navigation."
By: R. A. Smith, M.A., Ph.D.

Group Secretary:
D. H. Hughes, c/o Pye Ltd., Radio Works, Cambridge.

The Television Society

The scheduled meeting is postponed—see meeting above for Radio Section of The Institution of Electrical Engineers.

Lecture Secretary:
G. Parr, 68, Compton Road, London, N.21.

The Institute of Physics

Date: November 8. Time: 7 p.m.
Held at: New Physics Theatre, Manchester University.
Lecture: "Contact Potentials."
By: Dr. F. A. Vick, O.B.E., F.Inst.P.
Note: This is a joint meeting of the Manchester and District Branch and the Electronics Group.

Secretary: Dr. F. A. Vick, O.B.E., F.Inst.P., Physics Dept., The University, Manchester, 13.

Date: November 9.
Held at: The University, Birmingham.
Lecture: "The Cavity Magnetron."
By: Dr. H. A. H. Boot.

Secretary: Dr. J. H. Nelson, A.Inst.P., Messrs. Joseph Lucas, Ltd., Birmingham.

Brit. I.R.E.

London Section

Date: November 21. Time: 6 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Lecture: "The Ionosphere and the Transmission of Radio Waves."
By: Professor G. W. O. Howe, D.Sc.

The Secretary:
The British Institution of Radio Engineers, 9, Bedford Square, W.C.1.

RADIO SOCIETIES

A number of Radio and Scientific Societies have resumed activity after the war and it is hoped to give notice of their meetings as often as space permits. The following have been received.

Whitefield and District Radio Society

This Society is now holding regular weekly meetings every Monday evening at 7.30 p.m. at the Stand Grammar School, Higher Lane, Whitefield.

Further particulars of membership, etc., are obtainable from the hon. secretary, Mr. E. Fearn, 4 Partington Street, Newton Heath, Manchester, 10.

West Middlesex Amateur Radio Club

The Club will meet regularly at the Southall Labour Hall Rooms on the second and fourth Wednesdays in each month at 7 p.m.

Further particulars are obtainable from

The Secretary, Mr. N. Priest, 7 Grange Road, Hayes, Middlesex.

Stockport Radio Society

The late Secretary has now left the district and his duties have now been taken up by Mr. L. Chappell, Heathfield, Buxton Road, Disley, Cheshire.

Oswestry and District Radio Society

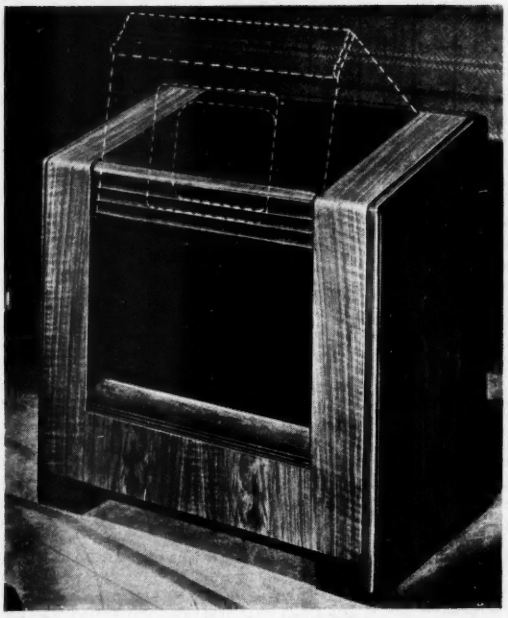
The above Society has now been formed and details may be obtained from the Secretary, Mr. A. D. Narraway, "Lamorna," Pant, Oswestry.

Ilford and District Radio Society

All meetings are held at: St. Albans Church Hall, Albert Road, Ilford.
Date: November 7. Time: 8 p.m.
Discussion.
Date: November 14. Time: 8 p.m.
Lecture: "Measurements in the Radio Field."
By: J. DeGruchy.
Date: November 21. Time: 8 p.m.
Lecture: "Television receiver construction."
By: E. G. Coe.
Date: November 28. Time: 8 p.m
Lecture: "New Developments in Speakers and Records."
By: H. A. Hartley.

Secretary: Mr. C. E. Largen, 44 Trelawney Road, Barkingside.

NOTES FROM THE INDUSTRY



PHILCO NEW TELEVISION RECEIVER

A feature of the first post-war television receiver announced by the Philco Radio & Television Corporation is that it is designed to be a piece of furniture when not in use.

When closed, the set resembles a sloping-front desk, and by pressing a button in the centre of the cabinet, the lid rises and brings up the screen of the tube for viewing.

Controls have been reduced to three—brightness, sound volume, and (an unusual one) sound tone control. The circuit is a 16-valve T.R.F. with a 12 in. tube. The preset controls are hidden in a recessed panel at the bottom of the cabinet, a position which facilitates adjustment when operating.

Mr. V. H. Gilbert

Mr. V. H. Gilbert, late of Radiovisor Parent, Ltd., has resigned his post as chief engineer and manager of technical development and is entering business on his own account. He will be glad to hear from business friends and acquaintances who may have electronic problems or requirements. His address is 180 Twickenham Road, Isleworth, Middlesex. Telephone: Hounslow 4710.

Mr. A. J. Maddock

Mr. A. J. Maddock, M.Sc., late of Standard Telephones and Cables, Ltd., and hon. secretary of the Electronics Group of the Institute of Physics, has taken up an appointment as head of the Electrical Instrument and Electronics Departments of the British Scientific Instruments Research Association. His new address is "Sira," Southill Road, Elmstead Woods, Chislehurst, Kent. Telephone: Imperial 3043.

Ardente Intercommunication Systems

A recent note on the Ardente Intercommunications Systems mentioned the "Loud-Hailer" equipment also manufactured by the same firm. Messrs. Ardente Acoustic Laboratories would like to acknowledge with thanks the part played by Messrs. Reslo (Sound Equipment), Ltd., during the war for the supply of loudspeakers in connexion with the large Admiralty contracts for this equipment.

New Midget Valves

Details of two new midget valves, designed for use in miniature radio receivers and hearing aids, have been released recently by the Park Royal Scientific Instrument Co.

The first, the Type 500 "Midgetron," is a voltage amplifier pentode with a filament voltage of 0.75 and maximum anode and screen voltages of 67.5. The mutual conductance is 0.25 mA/V and the impedance 1.0 meg.

The power output pentode Type 501 has a filament voltage of 1.5 and a filament current of 50 mA. The mutual conductance is 0.8 mA/V and the impedance 74,000 (*see* photo).

The overall dimensions of the valves are 35 and 43 mm. respectively and the bulb is 12 mm. diameter.

This Company also supply a miniature neon tube, Type 508, measuring 45 mm. by 7 mm. and having a striking voltage of 110 D.C. On 220 V the series resistance (which should never be omitted) is 0.25 meg.

The agency for these tubes in this country is held by Messrs. Runbaken of Manchester, but export inquiries should be addressed to the makers.

Full particulars and prices can be obtained from the Park Royal Scientific Instrument Co., 52 Minerva Road, N.W.10.

British Industries Fair, 1947

The first British Industries Fair since 1939 will be held from May 5 to 16 next year, and as in pre-war years exhibits will be grouped in two main sections: the lighter industries in London and the engineering and hardware at Birmingham. The London section of the Fair is organised by the Export Promotions Department, Board of Trade, 35 Old Queen Street, S.W.1, and the engineering section by the Birmingham Chamber of Commerce, 95 New Street, Birmingham, 2.

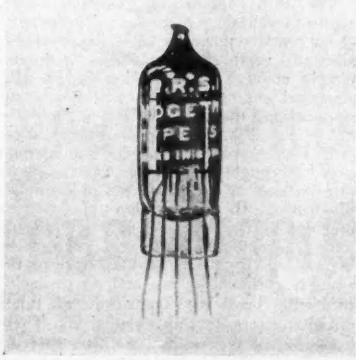
P.I.C.A.O.

The letters stand for Provisional International Civil Aviation Organisation, and are printed on a booklet of Demonstrations of Radio Aids to Civil Aviation issued by H.M. Stationary Office. The contents describe the radio aids which were demonstrated in Britain during September, 1946, and include long and short range navigational aids, area control and landing aids, and long, medium and short range communication systems. There is also a section on ancillary apparatus (trainers and test equipment) and some good photographs illustrating the trend towards "miniaturisation" (what a word!) of components.

The book is excellently produced at 5s., and should be a valuable reference for all concerned with radio and aviation.

Measuring Instruments (Pullin Ltd.)

In an advertisement of Measuring Instruments (Pullin), Ltd., that appeared in a recent issue of this publication an incorrect price of £8 was given for the M.I.P. Series 100 Multi Range Test Set. Readers should note that the correct price is £8 10s.



BOOK REVIEWS

Elementary Electric-Circuit Theory

By R. H. Frazier. McGraw-Hill. 425 pages. 267 Figs. (Price 20s. net.)

One of the lessons the war has taught us is that general principles in one branch of science are applicable to another apparently quite different branch. The author of this book shows that this is also true of branches of the same subject, and he points out in the preface that differences in procedures for solving electric-circuit problems in power, communication and electronic engineering arise not from differences of principle but from differences in emphasis of detail. The book concerns itself with elementary electric-circuit theory, starting with resistance networks having D.C. applied voltages and finishing with impedance networks to which are applied composite A.C. voltages. Besides the eight chapters there is an appendix, and at the conclusion of each chapter are a résumé and a series of questions and problems.

The first chapter defines electric-circuit conditions and concepts, giving an elementary dissertation on the generation and use of electric energy, and the differences in viewpoint between the power and communications engineer. There is also a discussion of distributed (field) effects and concentrated (circuit) effects. Symbols, terminology, units, diagrammatic representation and instruments complete this long introductory chapter of 69 pages. A word of warning to English readers—the symbols and unit abbreviations are not identical with those recommended by B.S.I. The use of λ for $\int v.dt$. will puzzle many who are familiar with the normal term for wavelength. Resistance networks and methods of calculating current and voltage components are the subjects of chapter II. Duality, reciprocity and superposition are fully discussed, as well as star-to-delta transformations and Thévenin's theorem. Several fully worked-out examples illustrate and clarify the theory.

The third chapter is concerned with elementary basic A.C. theory. The symbol Q for reactive power is not a happy choice since to most radio engineers it immediately conveys magnification factor. No electrical engineer, be he power or communications man, can afford to be without a sound knowledge of complex algebra, and chapter IV covers the ground very thoroughly, starting from vectors and passing on to a full set of examples illustrating the application of complex algebra to the solution of circuit problems. Chapter V is the A.C. counterpart of chapter II. Special examples show the general principles in action to solve problems involving transformers, tuned circuits, street lighting circuits, etc. There is a final section on the derivation and construction of impedance and admittance locus diagrams.

Chapter VI is devoted to Fourier analysis, and the discussion passes on quite naturally to filters and the behaviour of networks under the action of non-sinusoidal E.M.F.'s. Chapter VII swings over more definitely to power problems dealing in detail with polyphase operation. Transient disturbance effects are considered in the last chapter, which is followed by an appendix containing wire tables (American sizes), skin effect curves for increase of resistance with increase of frequency, certain selected physical constants, and tables of trigonometric and natural logarithmic functions.

The book leaves the reviewer with a feeling of disappointment; the impression is that a series of university lectures have been collected and bound together, for the unity which a book should give is lacking. A good deal of this dissatisfaction arises out of the first chapter which, for an introductory one, occupies an excessive length, a little more than 1/6th of the whole. It is suggested that an improvement would be made by delaying discussion of electric field effects to a later stage, and removing instruments to another chapter. More could also be done to stress that differences between power and communication problems are matters of detail and not principle. The transformer and rectifier smoothing filter offer an excellent opportunity of illustrating this point, and paragraph 13 on page 206 might have been expanded to cover this aspect more fully.

Minor points of criticism are the rather frequent use of footnotes, the failure to provide answers to the numerical problems at the end of each chapter, and the lack of a contents page giving the main section headings. On page 180 the diagram showing voltage as the reference vector for a series circuit makes it difficult to line-up the real and imaginary axes with the components of the complex impedance. This disappears if current is taken as the reference vector. The jump into series forms for the sine and cosine functions on page 166 hardly accords with the elementary character of the previous chapter.

In spite of these defects, which are all remediable, the book will prove useful to the second and third year university student in electrical engineering, and the wide selection of problems will make it particularly valuable for tutorial work in electric-circuit theory.

K. R. STURLEY.

Soul of Lodestone : The Background of Magnetical Science

By Alfred Still, 223 pp. (Murray Hill Books Inc., N.Y., $2.50).

Writing of Gilbert's work on the magnet, the author says: "Admitting he was a fine fellow . . . we may yet be inclined to ask 'But what, after all his twenty years of experimenting and pondering—what did he really know about magnetism?' The answer, if we are to be reasonably honest must be 'Very little.'

But let us ask another question: 'What does the physicist of our day know about magnetism? What do we, after more than three centuries of scientific progress, know about magnetism?' The answer, governed by the same qualification, will have to be: 'Very little.'"

Prof. Still does not, then, attempt to answer the question "What is magnetism?" Rather does he trace the growth of the science from the fables of the pre-Gilbertian era to the lines of force visualised by Faraday, dwelling on the influence of contemporary thought at all stages on the theories which attempted to explain the mystery of magnetic attraction.

This account divides almost sharply into the pre- and post-Gilbert eras. The masterpiece *De Magnete* not only created the science of terrestrial magnetism, but, as Fleming said, "marked a distinct epoch in philosophic thought."

How far this philosophic thought was leading science can be appreciated when it is noted that twenty years after Gilbert's book appeared, van Helmont was still theorising on the stupefying influence of garlic on the virtue of the lodestone. It was Porta who demonstrated that breathing onions over a compass did not make it lose its property—a simple experiment that was beneath the intuitive faculties of the ancient philosophers!

The historian will not find all the details of the development of the compass in this book, or even the horseshoe magnet, and he may feel that the sentence "In 1876 the extremely accurate Thomson (Kelvin) compass was introduced and adopted by the British Navy"

Books reviewed in this Journal can be obtained from

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If not in stock, they will be obtained from the Publishers when available

gives little indication of the trials of Lord Kelvin under the apathy of Admiralty officials. In point of fact, although his compass had been tested and successfully reported on by the Merchant Navy and by nearly every Navy in Europe, it was not until 1879 that the Lords Commissioners were graciously pleased to accept a compass for trial at Kelvin's own expense!

The author's final chapters, if they do not give us a clue to the answer to "What is magnetism?" console us with the thought that we may have discovered all that it is good for us to know, and that the answer to "How?" is more easily obtained than the answer to "Why?" In these days of cheap textbooks, ill-prepared and often inaccurate, it is refreshto read a scholarly book written in lucid English and abounding with quotable paragraphs.

Silvanus Thompson would have liked to have written such a book—a review from his pen would certainly have done it more justice.

G. PARR

Whittaker's Electrical Engineer's Pocket Book

913 pp. Edited by R. E. Neale (Pitman 30s. net.)

This is the seventh edition of this well-known pocket book (the term is a little euphemistic, as the book is 2 in. thick!) and the editor states in the preface that it has been almost completely re-written to bring it into line with current practice.

While this may be true of certain sections dealing with the generation and transmission of electricity, the reader may feel that there is yet a great deal more to be re-written in order to bring the book uniformly up to date as a standard reference work.

This is, of course, one of the difficulties of an editor. His authors may be scattered, particularly as the edition was probably prepared towards the end of the war, and he may be unwilling to make drastic alterations to the text in their absence, or hand the material to someone else to revise.

As an example of a section which needs complete revision, there is the chapter on Oscillographs which continues to show the Braun cold-cathode tube of 1900 and does not mention the new-fangled method of focusing the cathode rays by means of an electric field.

The whole science of thermionics is covered in six pages, which includes a sketchy outline of valve theory. There is no mention of the newer magnetic materials such as Alnico and Ticonal. Other examples of more direct concern to the power engineer might be quoted.

The time has come when it might be worth considering the publication of pocket books in two sections: the first, dealing with fundamentals, could be re-printed from time to time almost without alteration; and the second, dealing with recent advances, could be modified to keep pace with developments with less trouble on the part of the editors and publisher.

G.P.

The Parallel Operation of Gasfilled Triodes

(*Continued from page* 338.)

voltage e_3, which is added to the normal anode voltage of tube No. 2 (Fig. 5c). This transient pulse causes a corresponding change in the critical grid voltage curve for tube No. 2 as shown, the result of which, with a given change in applied grid voltage, is to cause tube No. 2 to strike within the period required for voltage e_2 to reach its maximum.

The introduction of inductance into the anode circuit will not normally have any harmful effects. It may be noted that when both tubes are conducting there is no relative rate of change of current, except for variations of arc drop which would give negligible effects in most cases, so that no trouble should be experienced with inductive voltage changes in the anode circuit.

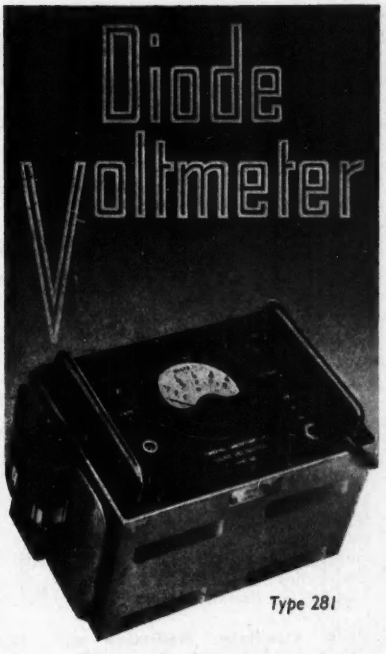
Tube Replacement Technique

The necessary provision for replacing either tube in a parallel circuit without interruption of working can be made simply by inserting a switch or plug and socket connexion in each anode lead. In the event of failure of either tube the procedure for its replacement is as follows:

1. Open anode circuit of faulty tube.
2. Remove faulty tube from socket.
3. Insert new tube.
4. Wait for appropriate cathode pre-heating time.
5. Reclose anode circuit.

This simple sequence of operations restores the circuit to its normal working condition.

In practice there may be some difficulty in deciding when a tube requires replacement, especially if the operation of the circuit is not greatly disturbed by the failure. There are probably not many applications where the complication of a current-failure indicator is warranted, but the provision of individual ammeters is a relatively simple solution in cases where there is regular inspection of the equipment, with the added advantage that such meters give a continuous indication of the relative loading of the tubes. In many types of tube the glow can be seen without difficulty, and the criterion of the necessity for replacement is then the attenuation or complete failure of the discharge, or such other symptoms as may be recognised from experience with the particular type of tube.



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ABSTRACTS OF ELECTRONIC LITERATURE

TELEVISION

Image Orthicon Camera

(R. D. Kell and G. C. Sziklai)

One of a series of developmental television cameras using the image orthicon is described. The complete camera weighs less than forty pounds. The input required by the camera is 300 watts. This power may be supplied by a non-regulated power supply or generator. A unique regulated high voltage supply was developed for the electron multiplier and image section of the camera tube. The camera circuits include the deflection system, voltage regulators, black-level setting, blanking circuits, and video amplifiers. A total of seventeen tubes is used in the camera. An extremely high-sensitivity version of the camera, using reflective optics, is also described.

—*R.C.A. Review*, March, 1946, p. 67.

Local Oscillator Radiation and its Effect on Television Picture Contrast

(E. W. Herold)

The objects of this paper are (1) to investigate the effect on a television receiver of a C.W. interfering signal which lies in the high end of the picture band, (2) to set up a maximum permissible interference level, and (3) to correlate this level with radiation from the local oscillator of superheterodyne receiver.

It was observed that the chief annoying effect of interference at the high end of the video band was a loss in contrast. A strong interference, in fact, caused a complete loss in contrast, or even a negative picture. Overall contrast gradation curves were computed theoretically which checked the experimental observations; the observations and computations indicated that a 20-decibels signal-to-interference field strength ratio at the antenna is a minimum satisfactory value. To maintain this ratio in a 500-microvolt permeter region of a desired transmitter, nearby receivers must have a radiation below 0.01 microwatts. Pre-war receivers, which used no radio frequency state, radiated 100,000 times unsatisfactory. A grounded-grid triode radio frequency stage may give a reduction of about 30 decibels or more, and a pentode radio frequency stage may be made even better. Other remedies are also discussed, but all increase receiver cost somewhat. However, it is made clear that an adequate television service will require suppression of radiation if the frequency assignments are such as to make interference possible.

—*R.C.A. Review*, March, 1946, p. 32.

CIRCUITS

Frequency Modulated Oscillator for Leak Hunting

(W. M. Brubaker and V. Wouk)

A circuit for converting a variable D.C. voltage signal into a frequency modulated audio-oscillation is described. The circuit can be used for general monitoring purposes, but this article confines the description to its use in conjunction with an ionixation gauge for leak hunting in vacuum systems. The oscillator enables one operator to hunt leaks more rapidly and effectively than two men calling out meter readings. Leaks representing pressure rises of less than 4×10^{-8} mm. of Hg have been found with an ionization gauge and this oscillator.

—*Rev. Sci. Inst.*, March, 1946, p. 97.

Decade Counting Circuits

(V. H. Regener)

A direct-coupled pentode trigger pair, previously described, is made the basis of two simple ring-of-ten circuits for high-speed counting. One of the circuits is especially suited for the counting of sharp pulses up to a frequency of 10 cycles per second. The other circuit is especially suited for frequency measurements on periodic currents of arbitrary wave form and of frequency from zero to above 10 cycles per second. The number of pulses or cycles counted by one ring-of-ten is indicated on the screen of a cathode-ray oscilloscope tube. Several of these ring-of-ten units, each with its cathode-ray tube, can be connected in cascade to make electronic counting with direct indication of the decimal figures possible.

—*Rev. Sci. Inst.*, Vol. 17, May, 1946, p. 185.

A Contact Modulated Amplifier to Replace Sensitive Suspension Galvanometers

(M. D. Liston, C. E. Quinn, W. E. Sergeant, and G. G. Scott)

The electronic amplifier, described is designed to measure extremely small D.C. and low frequency A.C. voltages in low impedance sources. Expressing the electrical noise in terms of equivalent input voltage with a 5-ohm input resistance and a 5-milliamp Esterline-Angus recorder, the maximum departure from the mean does not exceed 1.5×10^{-9} volt. Under laboratory conditions the drift is less than 5×10^{-9} volt over a period of 8 hours. The amplifier is compact and rugged, and it is not affected by vibrations or accelerations experienced in moving vehicles. At present the amplifier is employed in the measurement of radiant energies in infra-red spectrographs. It is also used for various laboratory and field measurements.

—*Rev. Sci. Inst.*, Vol. 17, May, 1946, p. 194.

Design and Use of Directly Coupled Pentode Trigger Pairs

(V. H. Regener)

A trigger circuit using two pentodes with direct anode to screen coupling is described. The mechanism of electrical stability and instability and the process of triggering are discussed. Sample diagrams for a pulse generator, an electronic switch, and a scaling circuit are given.

—*Rev. Sci. Inst.*, Vol. 17, May, 1946, p. 180.

THERMIONIC DEVICES

The Hydrogen Thyratron

(H. Heins)

A thyratron of special design was used as a switch in early radar systems to replace the rotary spark gap. The hydrogen thyratron, described in the article, is controlled by applying a trigger voltage at desired repetition rate to the grid. The advantages claimed for this device include light weight and compactness, precision timing, flexibility of operation, relatively low tube drop at high peak currents, and operation over wide ambient temperatures. The use of hydrogen introduces certain difficulties which are detrimental to the life of the tube. Particular applications mentioned are: pulse communication systems for multichannel operation, high-speed welding, electroplating with increased speed, and high-speed photography.

—*Instruments, April*, 1946, p. 211.*

The Calculation of Amplifier Valve Characteristics

(G. Liebmann)

The anode-current/grid-voltage characteristics of valves are determined with the help of diagrams and design charts based on Langmuir's data on the current flow in plane diodes with consideration of initial electron velocities, and on Oertel's and Herne's equations for the extended to multi-grid valves and to valves possessing a more complicated shape. Special attention is given to the "variable-mu effect," which represents one of the limiting factors in practical valve construction. A simple expression describing this effect is derived, and a chart of the "variable-mu constant" is presented, in which space charge is taken into account. Measurements on specially made experimental valves and on several types of modern mass-produced valves confirm the treatment of the variable-mu effect and show that the methods outlined in the paper, forming a complete design system, allow the prediction of the static valve characteristic with good accuracy even in closely spaced modern valves.

—*Jour. I.E.E.*, Vol. 93, Pt. 3, May, 1946, p. 138.

* Abstracts supplied by the courtesy of Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester

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The Input Impedance of a Cathode Follower

A Useful Demonstration Device

The circuit of Fig. 1, with components laid out on a "bread board" in the form of the circuit diagram, has been found to give a most convincing demonstration of the high input impedance of a cathode follower, for instructional use.

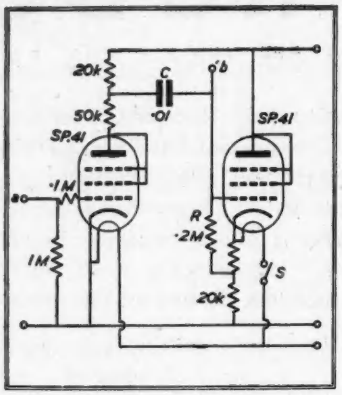

Fig. 1 (left.)

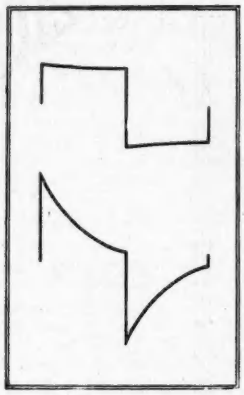

Fig. 2 (right).

A 50-cycle sine wave (the CAL voltage from a Cossor oscilloscope serves well) is fed in at *a* in Fig. 1. Valve V_1 is a squarer, and the square wave at its anode, first slightly attenuated, passes through the *CR* circuit of which *R* is the grid resistance of the cathode follower V_2. The waveform at *b* is displayed on an oscilloscope.

With the switch *S* open, the cathode follower is inoperative and the time constant of the *CR* circuit is short (1/500 sec.) compared to the duration of the square wave. The lower waveform of Fig. 2, a "differentiated" waveform, is displayed. When *S* is closed, the action of the cathode follower multiplies the effective value of *R* by $\frac{(\mu + 1)R_k + \rho}{R_k + \rho}$, in this case approx. 50. A long time constant is therefore produced, and the waveform will be seen to convert itself slowly to the upper waveform of Fig. 2, as the cathode follower warms up. This slow change makes the demonstration mose effective.

F. DUERDEN.

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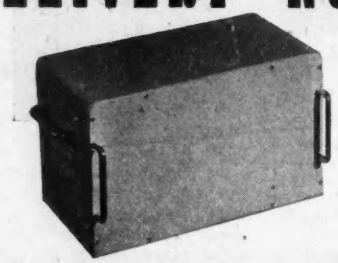

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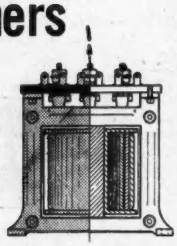

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MANUFACTURING facilities are available for producing power transformers and smoothing chokes from 10 V.A. to 10 K.V.A., designed and manufactured by S.E.M. engineers.

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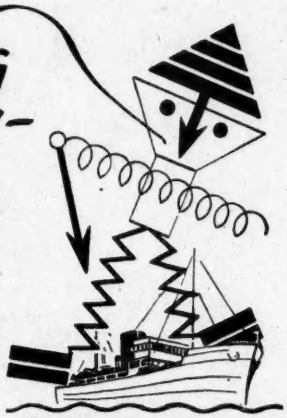

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High Grade Vitreous Enamels used on our Tropical Resistors give long life, and definitely assist in the trouble-free manufacture and performance of Radio Receivers, Television and Test Equipment.

Processed up to the highest Service Standards at a competitive price.

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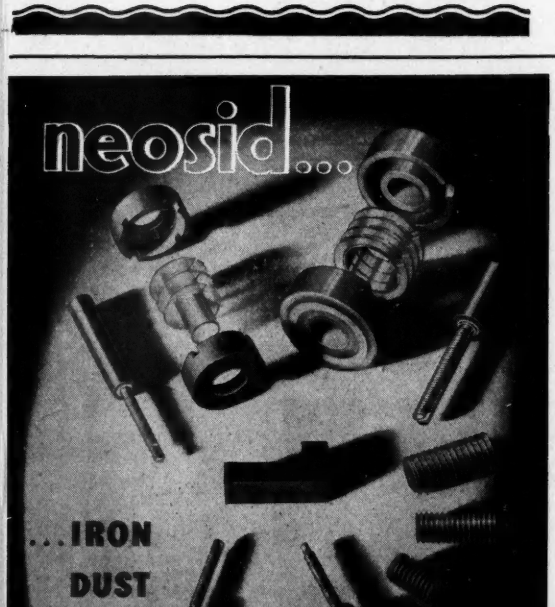

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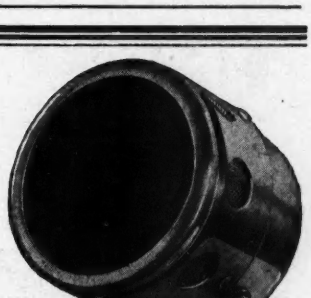

Diameter, 3 in.
Depth, 2½ in.
Weight, 2lbs.
Coil impedence, 6 ohms at 400 c.p.s.
Average impedence, 50-10,000 c.p.s., 8.9 ohms.
Finish: Nickel plate.
Output for normal close speech across transformer with 250,000 secondary load; 0.20 volts.

A MOVING COIL MICROPHONE FOR SPECIAL APPLICATIONS

Adequate frequency response: 70-8,500 c.p.s. approx.: low impedance, giving maximum protection against both R.F. and L.F. feedback. No polarising current required; no background; robustness; high sensitivity and no pronounced resonances are characteristics of this microphone.

Inevitable minute variations from model to model make it impossible to publish figures which are 100% correct in every case. We can, however, guarantee that these variations are small enough not to affect the performance.

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If we sacrificed quality for quantity, production would go up and our reputation would go down. That is a course we would never pursue. Bulgin quality will always be there. Sooner than you think, the quantity you need will be there also.

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The charge for miscellaneous advertisements on this page is 12 words or less, 4/- and 4d. for every additional word. Box numbers count as four words, plus 1/- extra for replies. Remittance should accompany advertisement. Cheques and P.O.'s payable to Hulton Press, Ltd., 43 Shoe Lane, E.C.4. Replies to box numbers should be addressed as above, marked "Elec. Engg." Press date: 15th of month for following issue.

FOR SALE

IN STOCK. Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc. Special Transformers quoted for.—University Radio, Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

ELECTRIC LIGHT glass multi fittings and a good selection of radio and electrical spares at a low cost. S.A.E. for list to Dioptrical Vision Aerial Co., 17, Mill Hill, Deal, Kent.

ROTARY TRANSFORMERS 150 watts: 12 volt input, 600v. 250 m/a output, 55s. 20 watts: 6v. input, 200v. 50 m/a output, 12v. input 480 v. 40 m/a output, 19s. Mail Order Supply, 24 New Road, London, E.1. Carriage extra.

SIEMENS 16 mm. cine camera for cathode ray tube photography. F.1.5 : 1/30–1/150 : 14–18 cms. 36v. operation. Ronson, 190 Bury New Road, Whitefield, Manchester. Whi: 2361.

ENGINEER going abroad must sell large collection of apparatus including microphones, loudspeakers, test gear and components. State wants or send stamp for list to Box 915, "Elec. Engg."

BACK NUMBERS of I.E.E. Journal 1934–1940. Particulars on request. J. L. Williams, 108 Bloomfield Road, Brislington, Bristol, 4.

0-1 mA METERS. First grade moving coil to A.I.D. specification. 2-in. scale. New. 20s. od. Mail order only. Paynter, 30, Capri Road, Addiscombe, Surrey.

COMMUNICATION RECEIVERS, several brand new models in stock including Canadian very high gain model covering 16-500 metres in three bands, A.C. operation B.F.O., R.F., and Radio Gain controls, completely self-contained in grey metal cabinet with speaker and fully guaranteed for one year. These models are in very short supply, price 32 gns. each. We can also supply these complete five waveband communication receivers in black crackle cabinets with separate speaker, 30 gns. U.H.F. communication receivers covering 90-126 m/cs, 12 valve complete with separate speaker, a superb instrument, 45 gns. Several 60 watt. A.C. amplifiers with twin channel mixing from 12 gns. Motor tuned T.R.F. Radio and amplifier, 10 watt output can be operated from any room or manually, 30 gns. Valves, type EF50 with valve holder, 12/- fully guaranteed. International Electronics, 655, Fulham Road, Walham Green, S.W.6. 'Phone: RENown 4178.

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LOUDSPEAKERS—We carry on. Sinclair Speakers, 12, Pembroke Street, N.1.

LOUDSPEAKER repairs, British, American, any make, moderate prices.—Sinclair Speakers, 12, Pembroke Street, N.1.

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MECHANICAL ENGINEERS to the Electronic Industry. Precision and Optical Instruments of all types designed and constructed in collaboration with Electronic Engineers. Tecnaphot, Ltd., East Union Street, Rugby.

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio, Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

TEST GEAR. Our 17 years' experience in supply of apparatus in kit form is at your service. New 10-page lists describe oscillators, multimeters, valvetesters, signal tracers, bridges, etc. Maclachlan and Co., Ltd., Strathyre.

ALUMINIUM SHEET, panels, chassis, cabinets, racks, plain or crackled. Complete equipment. components, metal valves, etc. S.A.E. lists. Amateur Radio Service, G6HP, Canning Street, Burnley.

EX-R.A.F. E.F. 50's, all tested O.K., with holders, 4 doz. Trade supplied. Write for new bargain list of other valves, etc. No callers. Mail only to 15, Dragon Square, Chesterton, Stoke-on-Trent.

THE NAME TO NOTE for all kinds of radio and electrical metalwork to specification, modern rust-proofing, all shapes and sizes undertaken, and for tropical use. Components and sub assemblies executed ω meet recognised wiring and material standards. Consultation, advice without obligation. Write: Department O1, Sea Rescue Equipment Ltd., Chiltern Works, Clarendon Road, Watford, Herts.

WE HAVE THE Largest Stock of English any American radio books in the country, including mand now out of print. Write or call for complete list. The Modern Book Co. (Dept. E.E.), 19/23, Praed Street, London, W.C.2 (PAD. 4185).

GREGG RADIO LTD., give you prompt and efficient trade repairs. Any part of this country. Quote Dept. H.W.1., 7 Bond Street, Hull, Yorks.

COMPONENTS FOR PROTOTYPES.—Commercial buyers for large industrial organisations, requiring components for prototypes (especially when they are in a hurry—which is mostly always) are gradually finding that the quickest way to get what they want is to 'phone Pad. 6116, or call at 177, Edgware Road (not far from Marble Arch) and take the goods away with them. No matter what is required, if we haven't got it in stock we always do our utmost to get it quickly, and we usually know where—and how.

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LABGEAR transmitting, and neutralising condensers and inductances; Labgear Crystal Calibrator at £13. 16s.; Cathode Ray Viewing Unit at £15; Absorption Wavemeters, from 15/6; Polystyrene Octal plug-in short wave Coils; Quartz Crystals; RTS Precision "LAB" Transformers covering every requirement including types such as 1750-1500-1250-0-1250-1500-1750 at 200 mA 0—2.5v. 5A 0-2-4 v.-4 A at £5 15. 6d.; Modulation Transformers; ±1 per cent Precision Resistors, etc. etc.,
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SUPERINTENDENT of Test Gear Section required by London firm of radio component makers. The responsibility involves design and maintenance of electronic test equipment. Degree or equivalent with industrial experience essential. Salary £500 upwards according to qualifications. Apply Box 899. "Elec. Engg."

JUNIOR ENGINEER required for the laboratory of a London firm of radio component makers. Degree or equivalent essential. Salary £400 upwards according to qualifications. Apply Box 900, "Elec. Engg."

SENIOR ENGINEER required for the laboratory of a London firm of radio component makers. Degree or equivalent with industrial experience essential. Salary £500 upwards according to qualifications. Apply Box 901, "Elec. Engg."

METALLURGIST required to undertake development work into the manufacture and application of tungsten carbide products. University degree preferred and experience in this field essential. Northampton or Swindon districts. Write stating age, experience, qualifications and salary required to Box 895, "Elec. Engg."

PROCESS CHEMIST, with analytical experience and degree or equivalent in chemistry, required to supervise pilot plant production and carry out development work in connection with electronic components. Northampton or Swindon districts. Write stating age, experience, qualifications and salary required to Box 896, "Elec. Engg."

CHEMIST required for development work on new type of cellulose acetate film for acoustic applications. Degree or equivalent in chemistry essential, plus experience of band casting machines. Northampton or Swindon districts. Write stating age, experience, qualifications and salary required to Box 897, "Elec. Engg."

METALLURGIST OR PHYSICIST required for development work on magnetic iron problems; degree or equivalent essential, plus preferably experience in some branch of powder metallurgy. Northampton or Swindon districts. Write stating age, experience, qualifications and salary required to Box 898, "Elec. Engg."

DEVELOPMENT ENGINEER required to supervise laboratory and development staff. Must have thorough knowledge and experience of L.F. and H.F., and television technique, with particular emphasis on audio frequency and acoustic work. Practical ability to direct and supervise is essential. London Area. Box 879, "Elec. Engg."

(Continued on next page)

CLASSIFIED ANNOUNCEMENTS (CONT.)

PRODUCTION ENGINEER required by well-known London firm of condenser manufacturers. Good salary and scope for right man, must have radio (preferably component) manufacturing experience. Box 874, "Elec. Engg."

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COMMUNICATION ENGINEER, possessing engineering degree or equivalent, and at least five years experience in the design for production of communication type receivers and transmitters (including F.M. equipment). West London area. Apply giving age, full details of education and experience, together with salary required to Box 910, "Elec. Engg."

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LARGE FIRM in London area extending its research and development department, requires physicists. Honours degree essential and some research experience desirable. Please reply to Box 905, "Elec. Engg."

TECHNICAL ASSISTANT required for University Physics Department for construction and maintenance of teaching and research equipment. Permanent post, good prospects, child allowance, pension scheme, salary according to age and experience. Interest in practical physics essential, experience instrument making and/or vacuum electronics desirable. Apply, quoting FAV, Professor of Physics, University, Manchester 13.

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VACANCIES EXIST in the Research Laboratories situated 25 miles from London of a large group of engineering and scientific companies, for senior engineers to take charge of: (1) Laboratory engaged on the design and development of industrial control equipment. (2) Laboratory engaged on the design and development of communication type radio receivers and transmitters. (3) Laboratory concerned with the theoretical design of electrical circuits embodying electronic devices. Applicants should hold first-class honours degrees in engineering or science and have had at least six years' experience in a laboratory. Age not less than 30 years. Initial salary £600-800 per annum. Applicants for vacancy 3 should have a good knowledge of advanced mathematics. Box 903, "Elec. Engg."

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LARGE FIRM in London area has vacancies in its development department for test gear engineers. Several years' experience in the design of electronic equipment is essential. Test gear assistants with experience in wiring and assembly of electronic equipment are also required. Write stating age, experience and salary required to Box 912, "Elec. Engg."

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RADIO VALVE Engineer required for development work in London area. Technical qualifications in engineering or physics, and several years experience of valve manufacture essential. Salary commensurate with ability. Write stating age, qualifications and experience to Box 918, "Elec. Engg."

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A long-felt want is met by the WEARITE ceramic rotary switches, supplied in individual wafers and components. You assemble any desired combination of contacts to make the finest low-loss switch yet devised. Ideal for the super-efficient receiver and high-grade instrument work. Ceramic switch wafers available in three standard contact arrangements :—

1 Pole 12 way	(use index type 12A)
2 Pole 6 way	(use index type 6A)
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Ceramic wafer	7/-
6 in. spindle with Index	4/-
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„ „ 3¾ in. „	4d.
„ „ 6 in. „	6d.
Spacers $\frac{1}{16}$ in. long	1½d.
„ ⅛ in. „	1½d.
„ 2 in. „	4d.
Moulded Straps	8d.
Nuts .. .. per dozen	3d.

One moulded strap is required for each wafer used. The 6 in. spindle supplied with the three types of Index can be readily cut down to required length.

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Complete ceramic 2 wafer switch, each wafer 1 pole 12 way .. **£1 : 1 : 10**

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Webb's 600 ohms feeder, something new. Ready built in lengths of 50 and 35 feet. Spacing 3½ in. with 18 gauge wire. Polythene spreaders securely moulded into wire every 20 inches, light and rigid construction. Supplied on drums ready for winding off, and immediate use.

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Special. Ten yard lengths of $\frac{7}{16}$ in. 80 ohms co-axial as above *fitted both ends with co-axial plugs and sockets.* (Supplied only in ten yard lengths) Per length with plug and sockets **15/-**

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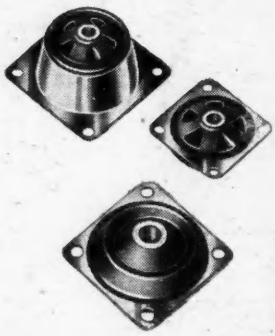
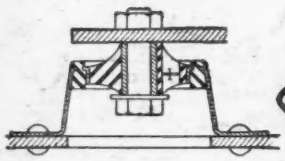
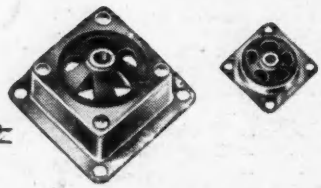
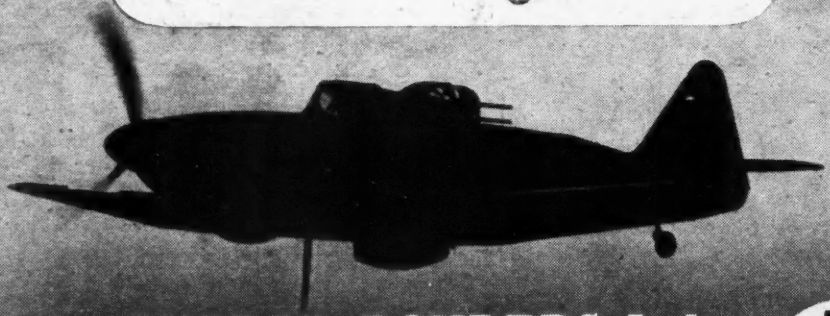
We should appreciate the opportunity of helping with *your* vibration problems.









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